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EDITOR

SURENDR JHA

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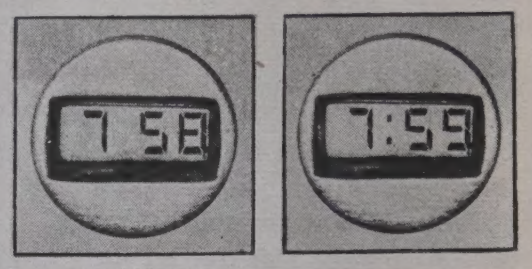
11 LIQUID CRYSTALS
N. V. Madhusudana
There are already watches and pocket calculators with liquid crystal displays. Some day, there may be photo-frame-thin wall TVs. Here's an account of what they are and how they work

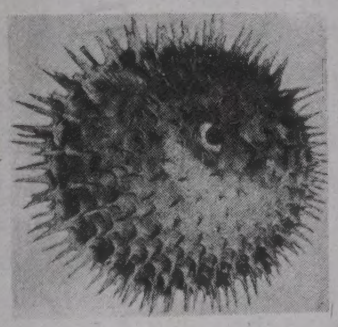


20 THE JUMPING GENES
V. Sritharan
Strange though it may seem, genes have been found to move freely in and about chromosomes, in viruses and in plasmids

23 LET'S GET TO KNOW OUR TREES
S. R. Amladi
This month : the fig family — banyans, pipals and various figs

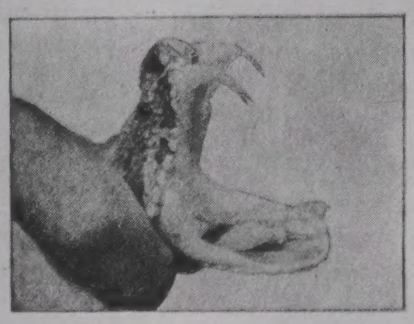
26-53 VENOMS
Man has no immunity from venoms and toxins — be they from creatures that lurk in the waters or on the soil or plants even. Here's a fully illustrated special feature

26 OF THOSE DEADLY DENIZENS OF THE SEAS
S. S. Bhattacharya



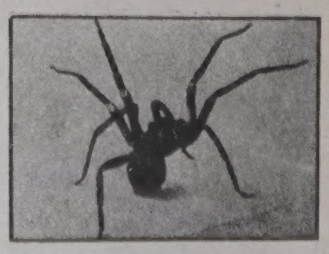
36 . . . AND SOME THAT MAKE DEADLY DISHES!
B. F. Chhapgar

43 POISONOUS PLANTS
N. Viswanathan



46 OF FANGS THAT KILL
M. B. Bhide & S. B. Bhise

52 SOME STINGING INSECTS
S. S. Jadhav
R. Whitaker



6 Letters
7 Science Shapes Life
17 Round-up of Research
21 In Lighter Moments
55 Ideas & Inventions
59 Books
61 Question & Answer
62 You Too Can Do It
62 Brain Teasers
63 Tell Us Why . . .

61 HOW ACCURATE IS THE RADIO-CARBON CLOCK?

65 INDEX TO VOLUME XI

LETTERS

Problems of pump stoves

As a housewife who has for years used the wick, pump and LPG stoves, I may point out that the pump stove (" Improving stove designs ", Letters, February 1977) develops a very high temperature which is not really needed. The skin of the vegetable turns black while the inside remains uncooked. Improvement in the efficiency of combustion alone will not help — the mode of heat transfer to all the material at the appropriate rate is important since our objective is to cook food and not melt the container. The nozzle and the deflection rings of the pump stove should be redesigned so that the available heat can be transferred through a wider flame area to the vessel. It is in this respect that the LPG stove is superior to the pump stove.

P. NAGESHWARI
17-1391/44
Subrahmanya Nagar
(Near Saidabad Colony)
Hyderabad-500 657

Air accidents

Congratulations for the excellent coverage on air accidents (March 1977). It would be no exaggeration to say that both Air India and Indian Airlines should make the March 1977 issue of SCIENCE TODAY a must-reading for their entire ground and air staff.

M. L. KOTHARI
Seth G. S. Medical College
Bombay-400 012

World record in shot putt

In *The Hindu* of 26 July 1975, I had read an article by K. O. Bosen in which he said the world record in the shot putt was 22·86 m held by Oldfield of USA. He made this record in a professional's athletic meet at El Paso, USA. Mr. Jal D. Pardivala says the world record is only 21·82 m. (February 1977). I don't know which one is correct.

VINCENT DE PAUL T. G.
Puravalappil House
P.O. Farook College
(Via) Feroke, Calicut
Kerala

■ **Mr. Pardivala writes: Mr. Vincent de Paul is right about Brian Oldfield's putt of 22·86 metres. This was achieved on 10 May 1975 at El Paso, Arizona, USA. However, this was done in a *professional athletic meet* conducted by the International Track Association.**

Athletic performances and records achieved by professionals are not recognised or ratified by the International Amateur Athletic Federation which is composed of 153 national federations.

The International Track Association mentioned above, at one time, was hoping to rekindle the public's interest in the professional side of the sport of athletics, but the venture did not prove successful.

The performance of 21·82 metres was reached by Allan Feuerbach (USA) on 5-5-73 at San Jose, California, USA. This was ratified by the International Amateur Athletic Federation. The IAAF very recently ratified the following two performances and they have been put in the Record Book:

21·85 m (71 ft 8½ in), Terence Albriton (USA), 21-2-76, Honolulu;
22·00 m (72 ft 2¼ in), Alexander Baryshinkov (USSR), 10-7-76, Paris.

The longest throw in history by an amateur has been achieved by George Woods (USA). The mark is 22·02 metres (72 ft 2¾ in). As this mark was achieved in an indoor competition, it did not receive official recognition.

For reasons beyond our control, the ninth instalment of the series " Learn While You Play " could not be published this month. We shall resume the series with the July 1977 issue.

— Ed.

Saving fuel in downhill drive

Mr. H. K. Sharma's device to save fuel in downhill run without free-wheeling (Ideas & Inventions, April 1977) will be a costly one for the user in the long run. If the fuel supply to the engine is cut off without switching off the ignition, the engine will obviously stop creating motive force, but its retarding action can only be used if the gears are kept engaged which will mean use of excessive force on the gear assembly thereby reducing the life of the gears and maybe spoiling a weak gear during the downhill journey itself.

Further, the speed of the vehicle will be reduced by a factor unacceptable to the driver. Also, the device is fit for use only in vehicles fitted with a fuel pump.

All four-wheeler vehicles and some two-wheelers (for instance the VIJAY) have an idle jet in the carburettor. With the help of this jet (carburettors not having an idle jet can be adjusted carefully) the idling speed of the engine can be adjusted very minutely.

While driving downhill, gears can be disengaged and pressure on the accelerator lifted. The supply to the engine will now be from the idle jet; thus, the consumption of fuel will be reduced considerably and the speed of the vehicle will be unhampered. Further, because of the live engine, if required, the braking action of the engine can be employed by engaging the higher gears irrespective of the type of the gear box. (In vehicles fitted with a constant mesh gear box, if the engine has stopped, gears, that, too, the first or second, can be engaged only after decreasing the speed to match the range of the gear.)

Thus, by this method we (i) save in fuel, (ii) gain in speed, and (iii) do not lose control over the vehicle.

RAJEEV LOCHAN SHARMA
E-1, New Colony
Sagar-470 002

New look of SCIENCE TODAY

We congratulate you for the new layout that your magazine has taken. There is absolutely no doubt that it can rank with the best science magazines anywhere.

A minor suggestion from us — why not give the names of those on your editorial staff as well?

S. SUNIL KUMAR
B. LAL MOHAN
Hostel No. 1, IIT
Powai, Bombay-400 076

Some thoughts on appropriate technology

It has become fashionable to talk of " appropriate technology " in every society. The only thing left unanswered is, how to deliver the goods?

According to statistics provided recently by A. R. Kidwai (*Employment News*, March 1977), India has the fourth largest S&T manpower in the world, next to only USSR, USA and France. Yet, with all the pride in our infrastructure based on a chain of enviable national laboratories and academic institutions, our public as well as private sector industrial organisations tend to prefer (and are likely to continue) importing technologies not only from the big three, but from other smaller countries, too. Could it be due to lack of interest (or faith) in the production organisations for relatively less productive (at least, on short-range basis) science (and R&D)?

Often the nation has tried to get " first rate " workers back from abroad and reduced them to " second rate " or even lower in their respective fields. Our young graduates, working scientists and technologists, in general, are honest and hard-working and desire to contribute to the most challenging problems of the times. What prevents them from contributing their share and reduces them soon to complacent or revolting persons?

When we talk of " appropriate technology " let us think of establishing a FOUNDATION for SCIENCE PROGRESS (FSP) to look after the health of the vital life of any technology. And let it not be a government body.

VINU TAYAL
F 10/5 Model Town
Delhi

CORRECTIONS

■ **The manufacturing cost of the single phasing preventor described by Mr. S. Tamilarasu (Letters, April 1977, p. 6) should read Rs. 30 and not Rs. 300 as printed.**

■ **The continuation line after the last line above Fig. 4, left-hand column, p. 32, in the article "Cotton fabrics and the finishing gimmicks " (April 1977) has been erroneously printed at the top of the next column.**

We regret the errors.

— Ed.

VIKING SNAPS A MARTIAN MOON

This photo-mosaic of Phobos, one of the Martian moons, was obtained by Viking-1 Orbiter in February from a distance of 400-650 km. The potato-shaped moon is about 21 km across and 19 km from top to bottom. Grooves are seen, the largest of which is 100-200 metres wide. One theory to explain these is that Phobos consists of layers and the photos show an edge view of the layers. The second theory is that they are shock wave patterns impressed on the satellite when the large crater Stickney was formed; and the third is that they are due to stresses set up by the gravitational pull of Mars, which has also caused the elongation of the satellite. The density of Phobos is about 2 gm/cm^3, much less than that of Mars, suggesting that both Phobos and its twin Deimos were acquired by capture.

SUNGLASSES MAY HARM YOUR EYES

While many wear them just to look smarter, even those who use them to protect their eyes from sunlight may not really be achieving their objective.

Two American scientists tested sunglasses purchased in various drug stores and found many of them optically unsatisfactory. One-third of their selection admitted more ultra-violet (UV) light (which is the fraction of sunlight that harms the eye) than visible light. The worst case was one which let in 70 per cent UV radiation of wavelength 360 nanometres (1 nanometre = 10^{-9} metre) compared to 20 per cent of 550 nanometres (visible light).

Writing in *Applied Optics* (**16**, 515, 1977), the scientists say that wearing sunglasses may be worse than not wearing them, because for one thing, when the amount of visible light is reduced, a much higher level of outside illumination may be tolerated, and hence the amount of UV radiation reaching the eye may be greater. Unfortunately, there is no correlation between the price, the lens colour or manufacturer and the UV transmission performance. At least in the consumers' interest, the manufacturer should indicate the transmission characteristics of their lenses over the solar spectrum.

In India, it appears that even window glass is being used for the manufacture of sunglasses. The Indian Standards Institution, at the instance of the National Society for the Prevention of Blindness, is now working out ISI standards for sunglasses.

THOSE WORRIED PILL-USERS!

Women using contraceptive pills are often worried by the 'rumoured' side-effects; however, the one which makes them worry most is the possibility of becoming infertile.

It is known that when women using contraceptive pills stop using them because they wish to have a baby, a small percentage of such women fail to conceive. There may be a total absence of menstrual periods or sometimes their ovaries may fail to release mature ova. This post-pill infertility may even make women look down upon the pill.

Now, a drug called Bromocriptine (2 brom-alpha-ergocryptine), derived from the fungus ergot, has been found to restore the regular ovulatory cycle in such women. Its use in treating certain hormonal diseases was recognised when it was known that it suppresses prolactin secretion by its action on the pituitary. The post-pill infertility may be caused by hyperprolactinaemia (an abnormality in prolactin secretion) induced by prolonged use of artificial oestrogen and progestogen in the pills. In such cases, Bromocriptine could possibly help.

A report published in the *Lancet* of 5 March 1977 (p. 502) describes the results of Bromocriptine administration to 19 women in a hospital in Utrecht who, although having normal serum prolactin levels, have become infertile as a post-pill effect. After treatment for between 6-12 weeks with this drug, 14 of the 19 women began to ovulate normally. This sounds attractive but the drug is extremely expensive and its side-effects, if any, are still unknown.

VIKING: WHAT NEXT?

Hopes of Martian life are not ruled out by the Viking mission's failure to detect any so far. Another site might have conditions entirely different from the landing sites of Vikings 1 and 2, and the next Martian mission, which will be a roving laboratory covering 100-1000 km of the planet's surface, might have better luck. Scheduled for launch in January 1984, the laboratory will implant 'penetrators' several metres deep below the Martian soil to determine its chemical composition and to record seismic activity.

Meanwhile, the Viking control centre is having difficulty in 'reading' Viking, though the two orbiting crafts are moving in their closest yet orbits of the planet. Surface features in the northern hemisphere, which is having its winter, are almost invisible due to haze, probably produced by ice crystals. In the southern hemisphere, the problem is dust, and scientists think Mars may be having one of its great dust-storms. Both the Landers, particularly Lander 2, which is only 43 degrees from the North polar cap, are feeling the cold. Most of the experiments have been switched off, except the seismometer and the meteorology package, and the craft has been put into low-key operation to keep its scientific instruments from freezing.

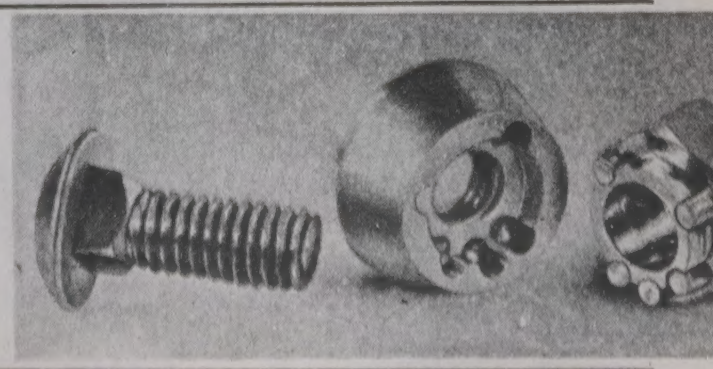
Still, Viking has been an unqualified success, and even up to last March, data was pouring in from the two Landers and Orbiters in such a torrent that publications could not keep up without delays of several months. Dr. Gerald A. Soffes, chief project scientist of Viking, hopes for an international Viking conference, similar to the one that followed the Mariner mission.

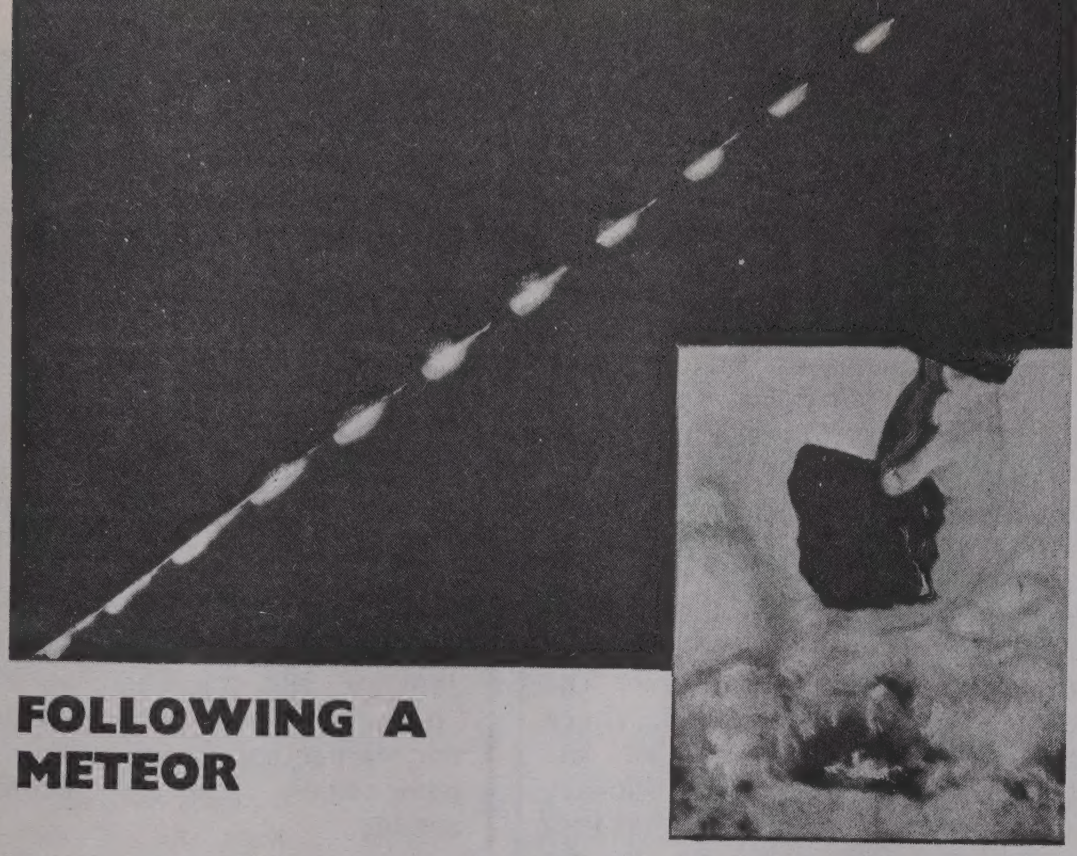
MAPPING NEW X-RAY SOURCES

An orbiting laboratory launched by NASA (the National Aeronautics and Space Administration of the United States) will study X-ray sources in the sky. Called HEAO-A (High Energy Astronomy Observatory), it will also study such mysterious objects as quasars (possibly the remotest observable objects in the universe), pulsars (fast-spinning neutron stars), radio galaxies, which emit powerful radio waves, and 'black holes' which are believed to represent stars that have collapsed into a

NUT THAT CAN BE LOCKED

This tapered lock-nut can be twisted off only by its keyed torque nut—useful as an anti-theft device for valuable things which have to be bolted down. Made by a US firm, it comes in many sizes and combinations.





FOLLOWING A METEOR

For seven years, the cameras of Canada's 12-station Meteorite Observation and Recovery Project had been on the look-out for the event — a meteorite fall — so that from the photographs not only could the meteorite be recovered but its orbit worked out. The cameras were automatic, being triggered by photometers reacting to the oncoming fireball.

Then it happened, on 5 February 1977. Airline pilots first reported the fiery descent, then scientists started checking on the project's cameras. One had caught the descent perfectly, though jerkily, because its focal plane shutter clicked four times a second; from this the meteorite's velocity through the upper atmosphere was calculated at 14·2 km/sec.; without the Earth's gravity it would have been only 8·9 km/sec. The data from the plates were fed into a computer and a search was made in the predicted impact area. Then on 12 February, Ian Halliday of the Hertzberg Institute of Astrophysics (Canada) found the irregular blackish rock on a farm near the town of Innisfree, Alberta (see photo). The 2·07 kg chondrite was the smallest of the three meteorites so far tracked by photography and recovered.

What's the earthly use of it? Just as a core drilled from the seabed can tell us a lot about the history of the Earth, a meteorite is informative to researchers who study it. A meteorite is a free-wheeling natural spacecraft — the Innisfree meteorite had an orbit whose aphelion (farthest point of orbit) lay within the orbit of Jupiter — having a natural record of cosmic rays, solar activity and other conditions of the environment it came from. One of the earlier meteorites thus recorded showed that the cosmic ray flux rises by about 20 per cent at a distance of 300 million km from the Earth. The solar wind, in fact, blankets off cosmic rays.

tremendously dense state and possess such high gravitational fields that even light cannot escape (SCIENCE TODAY, May 1977, p. 13).

But the basic mission of HEAO-A will be to map new X-ray sources and to investigate the shape and structure of these sources. Normally, the Earth's atmosphere filters out X-rays reaching its surface. Some earlier attempts to study celestial X-ray sources were by sending up rockets and balloons with instruments — these were brief flights.

About 200 X-ray sources are known, but the new observatory could expand this to thousands during its six-month mission.

Originally, it was planned that the observatory during its end-over-end rotation would survey the entire sky. Later, it was decided that this scanning rotation should be stopped at various portions of the orbit to point at specific X-ray sources.

In 1983 a space telescope is scheduled to be launched from the Space Shuttle (see SCIENCE TODAY, February 1976, p. 55). The 2·4 m telescope will have, as one of its scientific objectives, the study of point X-ray sources.

WISDOM FROM WASTE

Americans are said to be the greatest wasters in history, but at least two persons there have winnowed wisdom from waste. They are William L. Rathge and Gail G. Harrison of the University of Arizona who examined refuse collected by the city sanitation division to study the response of householders to rising food costs. They found that the total quantity of food brought into households of all income levels decreased between 1973 and 1974, but that decline continued in 1975 only for the higher income groups. All groups purchased less solid animal protein food and lower income groups increased their purchase of grain products.

In defence of their method, the researches say that archaeologists have long used refuse from ancient cultures to reconstruct social behaviour.

AN EGG-SHELL FOR EVERY HEIGHT

The shelled egg was a great biological invention. It freed animals from the necessity of having to return to water to breed. It is a capsule containing all the nutrients needed by the growing embryo, and water and air as well.

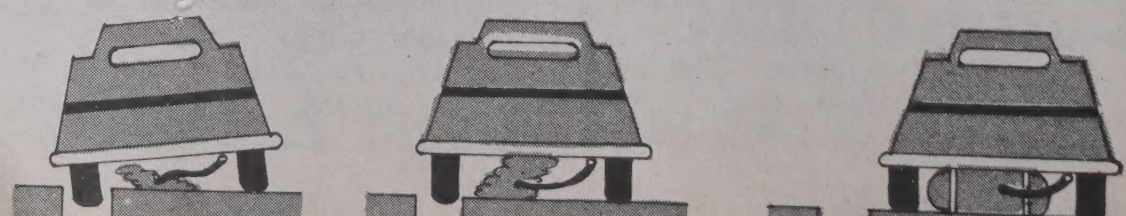
During incubation, the water content gets reduced gradually owing to the loss of water vapour to the atmosphere through the pores in the egg-shell. This loss enables the formation of an air-space at the big end of the egg, and this space is the source of the first breaths taken by the embryo. However, the loss of too much water could harm the development of the embryo, and the porosity of the egg provides a delicate balance between the need for air and for water. Hence, it is reasonable to except that in mountain birds the egg-shells would be less porous, because at higher altitudes the atmospheric pressure is less, and water molecules diffuse more rapidly. This is just what three zoologists, Gary C. Packard, Paul R. Sotherland, and Mary J. Packard, of Colorado State University (USA) have found.

Collecting eggs from the nests of barn swallows (*Hirundo rustica*) at different altitudes in Colorado, they placed them in desiccators above flakes of potassium hydroxide to maintain a dry atmosphere, and weighed them at 24-hour intervals. They found a more than proportional relationship between altitude and egg-shell porosity. Earlier studies with eggs of domestic fowls maintained for several generations at high altitudes also showed

A GAS-BAG CAR JACK

Patented by a Japanese firm, this reinforced nylon bag can lift up a car for wheel change (in case of a puncture) or to free the wheels stuck in a ditch. The bag placed under the chassis can be inflated by plugging its inlet valve by a hose to the car exhaust pipe. As the engine is revved up, the bag inflates and takes on a cylindrical shape and lifts the wheels off the ground.

In case of a wheel stuck in a ditch, the bag is placed under the chassis with a fold on one side; this makes the inflated bag stand up with a tilt to one side; at the same time as the wheels are freed, the tilted bag also topples over to its side and rolls on the ground, making the car move with it — away from the ditch.



reduction in the egg-shell porosity, d this reduction was just enough to mpensate for the increased diffusivity water vapour; the high altitude fowls' gs were also of reduced size, which ve them a smaller shell area.

Writing in *Nature* (*266*, 255), the entists hypothesise that since shell rosity is an inherited characteristic, en it is combined with a tendency for ds to return to the locality in which y were born, it is possible that natural ection acts upon minute variations in rosity, so that the survival rate becomes ater in individuals with less porous gs.

IVAL FOR RUBBER

Faced with a shortage of rubber, both nthetic and natural, the United States s turned to guayale (pronounced -oo-lee) a natural rubber-bearing ub that grows wild on the high, arid teaus of Mexico and Texas. The mand for natural rubber, about 30 per nt of the total rubber used, is increasing cause radial tyres, which are increasing popularity, are using up to 40 per cent tural rubber. Rubber from guayale *arthenium argentatum*, which belongs the same genus as the weed which s been found to cause a serious skin ergy in India) is practically indistin-ishable from natural rubber.

Seventy years ago, the shrub provided lf the rubber used in the US, but the ocessing was uneconomic because the rubs had to be harvested, pulped, and en parboiled, whereas rubber from the vea tree can be tapped straight off it. search in Mexico is now concentrating improving the processing, while nerican research will be on the cultiva-n part. But profitable guayale rubber is pected to be some 20 years out in the ture.

HE BACTERIA'S NTI-ANTIBIOTIC

More and more antibiotics are being ut on the shelf because of the develop-ent of bacterial resistance. Scientists w suspect that bacteria possess genes at make antibiotics ineffective, and at, at least in some cases, such genes me from the very organism that oduced the antibiotic.

Julian Davies, a University of Wisconsin JSA) scientist and his team took genes om a bacterium, *Bacillus circulans*, hich makes the antibiotic butirosin, ttached them to a plasmid (a ring of NA in the cytoplasm) and transplanted em into *Escherichia coli* bacteria, cur-ntly the pet of the molecular biologists. he genes, which in the donor bacteria roduce an enzyme which modifies utirosin, now made the *E. coli* resistant butirosin. The enzyme didn't inactivate ll of the drug; some of the inactivated ntibiotic went to prevent further anti-iotic from entering the cell. According the researchers, the work, tn addition elucidating antibiotic resistance, also uggests that genes may move freely etween bacterial species in nature.

CAN WE CHOOSE BETWEEN THE TWO POLIO VACCINES?

It is generally agreed that both Salk's killed polio virus vaccine and Sabin's live and attenuated virus (oral) vaccine are highly potent and safe in the fight against polio. Sabin's oral polio vaccine (OPV) has been preferred since 1960 in most parts of the world mainly because it is thought to produce longer lasting immunity besides offering protection against the 'wild' type of polio virus also. Another reason for its acceptance is the ease of administration: it can be given orally. However, Sabin's vaccine is known to be associated with a small number of polio cases.

In 1970, a court case in which an eight-month old girl contracted paralytic polio shortly after receiving a dose of Sabin vaccine, renewed Salk's interest in the area. (He had first developed a killed virus vaccine against polio during the 1950s.) Salk argued that his killed virus vaccine should replace the live vaccine which is less safe than was previously thought and that his vaccine should be recommended for routine immunisation. (He is of the opinion that the live vaccine may be used in isolated outbreaks.)

From the safety point of view, the scale would seem to tip in favour of Salk's killed virus vaccine. It also seems to be well suited for children who have a defective immune system or adults who have not been vaccinated before and want to enter areas where polio is endemic. One more point against Sabin's vaccine is that, if the child already harbours other intestinal viruses, they may interfere with the effectiveness of the oral vaccine; such conditions are very common in tropical countries like India (see SCIENCE TODAY, November 1972).

However, Salk's vaccine is much more expensive than Sabin's vaccine. But then, it is extremely costly to preserve Sabin's oral vaccine in the tropical heat.

Is there a choice, really? Nobody knows — as yet!

MOVIE MAGIC

(Left) Actor Peter Fonda was covered completely with white make-up. He was then photographed from all angles with grid lines projected on his body. The grid information fed to a computer produced the sequence below

If you have seen the sci-fi movie *2001 : A Space Odyssey*, called " the greatest special effects film ever made ", you must have wondered how some of the tricks were done — astronauts floating in zero gravity, a space station wheeling in its orbit, etc. The new movie *Futureworld* is said to go one better. What electronics people call computer graphics is employed to obtain virtually any image simply by turning knobs. An object can be made to move in any direction, to tilt or split in two. The results are somewhat similar to old-fashioned hand-drawn animation, used for movie cartoons, but infinitely more dramatic and faster.

One sequence in *Futureworld* shows scientists attempting to make a clone or duplicate of actor Peter Fonda. The scene shows what looks like a Plaster of Paris bust of Fonda, except that you seem to be looking up into a sort of cutaway cylinder of his neck right into his skull. Then the bust rotates and the camera shows the top of his head gleaming like chrome.

This scene, the like of which it is claimed has never been screened before, was produced by photographing Fonda with three movie cameras 45° apart, one frame at a time, while a man hiding on the floor under a black cloth, rotated Fonda between 'takes'. Next, from large blow-ups placed beneath a 'digitising table' criss-crossed by thousands of wires, hand tracings were made of each polygon that made up the bust. These were reduced to over 4,000 triangles and rectangles that made up the full 3-D image and 'written' on to magnetic tape and combined with a computer program to produce the eerie 3-D image of Fonda on the screen.

Paul Schneider, Mr. Tarzan, says:

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LIQUID CRYSTALS

N. V. MADHUSUDANA

It looks like a blank picture frame on the wall. Push a button and the blank panel becomes alive with television ages. A wall TV? Does it sound o futuristic? Actually, it is not ogether beyond the realms of possi- ity with liquid crystal TV screens. ne liquid crystal watch and the uid crystal pocket calculator are o new electronic devices that have eady been introduced into the nsumer market during the last year two. In the watch, the digits ndicating the hour and the minute), in the calculator, the results of e calculations, are shown up by eans of liquid crystal displays CDs) which have the advantage at they consume the least electrical wer of all known types of display stems. It is estimated that the world mand for LCD watch displays likely to be about 15 million during 77. The additional requirements r clocks, calculators, digital meters, c are also expected to be consider- le. So, calculated at even a few pees a digit, it is evident that this dustry runs into some tens of crores rupees.

What are liquid crystals? As the me suggests, they are states of atter intermediate between the quid and the crystalline state. They ve some properties characteristic liquids and some others character- ic of crystals. The crystalline state as a regular three-dimensional rangement of the constituent atoms molecules (Fig. 1a); this accounts r the regular external shapes that ystals possess. If we try to deform a ystal, elastic forces will oppose the eformation. On the other hand, ough the liquid phase is a con- ensed state of matter, it possesses no long range order of molecules and, hence, is doomed to flow, to assume the shape of the container and to form a meniscus.

It is a matter of common experience that when a crystal melts, it is transformed to the liquid phase. However, if the crystal consists of long rod-like molecules, its melting behaviour can be quite complicated. It may exhibit two or sometimes more melting points; in other words, when the solid crystal is heated, it may pass through one or more intermediate phases before it finally goes over to the ordinary (isotropic) liquid state. In these intermediate phases, the material is viscous and, in bulk, is usually turbid and quite distinct in appearance from the normal liquid. These phases are termed as liquid crystalline phases or mesophases.

Liquid crystals flow and take the shape of their containers. At the same time, the molecules tend to remain parallel to one another; in some cases they form one-dimensional or two-dimensional arrays, rather reminiscent of a crystal (but never a complete three-dimensional array as in a solid crystal). Thus, a liquid crystal has the mobility of a viscous liquid along with certain other properties typical of a solid. For example, one class of liquid crystal reflects brilliant colours exactly like iridescent opal.

Liquid crystals are classified broadly into three types: nematic, cholesteric and smectic.

Nematic liquid crystals

The nematic is the simplest type of liquid crystal and has a pure *orientational* long range order of molecules: the long axes of the molecules are approximately parallel to one another (Fig. 1b). Each molecule can rotate around its axis and move sideways or up and down along its length, like matchsticks in a box. The degree of orientational order decreases with increase of temperature, till the nematic-isotropic transition point is reached. At this temperature, a first order (discontinuous) phase transition takes place with a weak latent heat of transition ($\sim$1 kilo joule/mole) and a small volume increase ($\sim$0·5 per cent). In the isotropic liquid phase, there is no long range order, either translational or orientational (Fig. 1c).

Fig. 1 Arrangement of rod like molecules in (a) crystal, (b) nematic liquid crystal, and (c) isotropic liquid

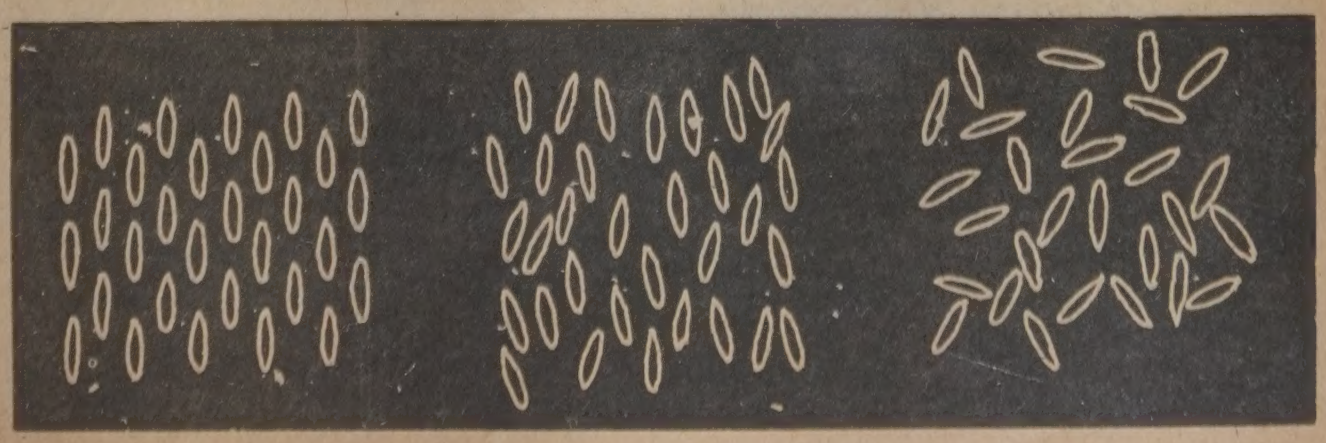


Fig. 2 Open drops of a nematic liquid crystal as viewed with crossed polaroids. The dark lines are known as ' threads '. The name *nematic*, meaning thread-like, is derived from such a texture (magnification × 400)

The spontaneous orientation of the molecules about a preferred axis, known as the director axis (**n**), gives rise to anisotropy in several properties of the nematic state. For example, the nematic is optically strongly birefringent or doubly refracting, the refractive index being different for light polarised parallel and perpendicular to the director axis. The birefringence is even much stronger than that of a solid crystal like calcite or quartz. Thus, when a perfectly oriented nematic liquid crystal film is viewed under a polarising microscope, its optical characteristics are rather similar to those of a crystal. However, unless special care is taken to orient the liquid crystal, one usually obtains complex optical patterns or ' textures '. These arise from defects in the structure and are useful in the identification of the mesophases. Some examples of textures of liquid crystals are shown in Figs. 2 and 3. Similarly, the diamagnetic and dielectric properties of nematic liquid crystals are also anisotropic. Experimentally, it is found that the director axis is non-polar, that is, **n** and $-\mathbf{n}$ cannot be distinguished.

The nematic also has elastic properties arising from the orientational deformation of the medium. When neighbouring regions do not have a common director axis, elastic restoring torques come into play. This is referred to as curvature elasticity, and is quite different from the usual elastic behaviour of solids. There are three independent curvature elastic coefficients, corresponding to splay (slant as of the side of a doorway, window, etc), twist and bend deformations, but their magnitudes are quite small, $\sim 10^{-6}$ cgs units, so that even moderate electric or magnetic fields can distort the medium.

The nematic liquid crystals do not possess translational order, and hence, flow like a liquid. Their viscous properties, as expected, are also anisotropic; in fact, there are five independent coefficients of viscosity. Further, the orientation induced by flow results in elastic torques. Thus, the hydrodynamics of nematics is quite complicated and, in general, involves three elastic and five viscosity coefficients. Typically, the apparent (or average) viscosity is of the order of 0·1 poise, which is a few times greater than that of an ordinary liquid.

Pure nematics are good insulators. They have to be doped with ionic impurities to make them electrically conducting. Because of the anisotropy in viscosity, the ionic mobilit and hence the electrical conductivit is also anisotropic. As we shall se later, this is a useful property i certain applications. Conductivitie of the order of $10^{-7} - 10^{-8}$ ohm^{-} cm^{-1} can easily be obtained b doping.

Cholesteric liquid crystals

The cholesteric state is essentially a nematic type of liquic crystal except that it is composed o optically active (with the ability t rotate the plane of vibration o polarised light) molecules and, hence has a spontaneous twist about an axis normal to the director (Fig. 4). The name arises from the fact that most compounds exhibiting this phase have a skeleton similar to the steroid cholesterol. The twisted structure may also be obtained by dissolving a few per cent of an optically active compound in any nematic liquid crystal. The helical arrangement can be either right- or left-handed and gives rise to some spectacular optical effects. The periodicity in the structure with a spacing equal to the pitch results in selective reflection of light, rather like the Bragg reflection of X-rays from crystals. Often, the pitch is of the order of the wavelength of visible light (4000 Å — 7000 Å). For light incident along the helical axis, the reflected light is strongly circularly polarised; one circular component, which may be right- or left-circular depending on whether the structure is right- or left-handed, is almost totally reflected, while the other component is transmitted unchanged. Moreover, the medium possesses a very high optical rotatory power, that is, the plane of

Fig. 3 Schlieren texture in a nematic liquid crystal. The points where the four dark lines meet arise from defects in the structure and are known as ' disclinations ' (of strength 1), in analogy with dislocations in crystals (magnification × 400)

risation of light is rotated by a thousand degrees/mm, which is a sand times greater than the tory power of a solid crystal like tz.

sually, the pitch of the helix ly decreases with increase of perature, and the wavelength of ction follows suit. For example, it be near the red region of the le spectrum at lower tempera-s, and change towards blue as the

4 Molecular arrangement in the lesteric liquid crystal

nperature is raised. In some com-unds, the variation can be quite id and, as we shall see later, they be used in thermography.

nectic liquid crystals

The smectic states characterised by a layered angement of molecules. Any two ers can slide over each other cause of the very weak forces be-een them. [Smectic means soap-e; many common soaps exhibit ectic phases at elevated tempera-es (~200°C) or in the presence water.] There are many sub-ssifications in the smectic type. ne simplest of them is smectic A ig. 5a). In this state, the mole-les are oriented normal to the yers, while the layer itself is liquid-e with no translational order. The yers can bend easily while still eserving their thicknesses. A dis-

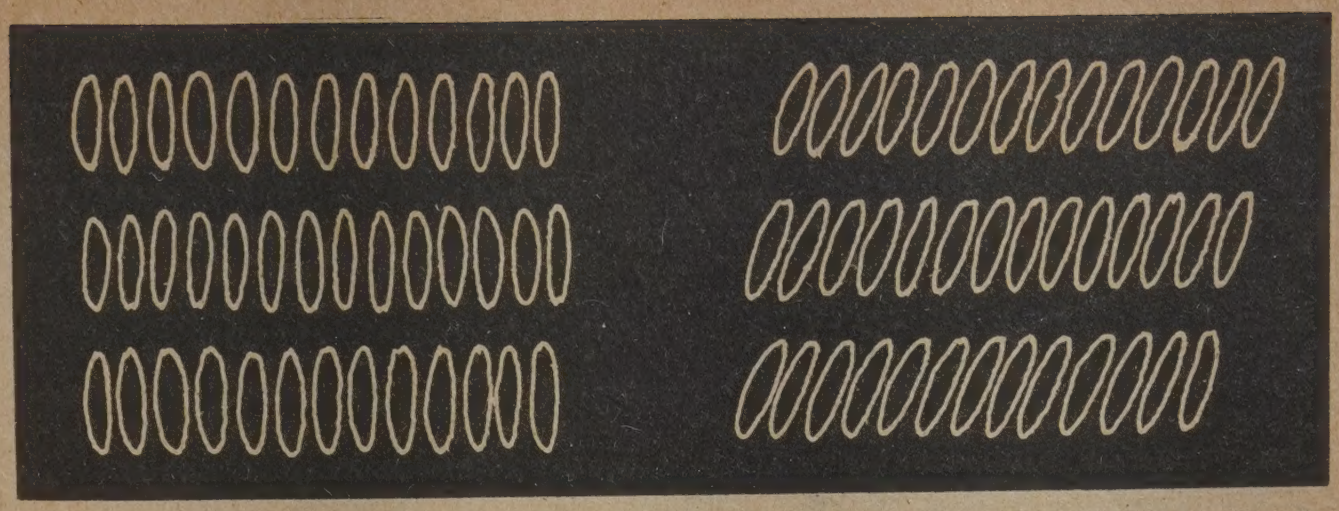


Fig. 5 Molecular arrangement in smectic A (left) and smectic C (right) liquid crystals

torted smectic medium forms characteristic textures, known as 'focal-conics' (Fig. 6). When the smectic A phase separates from either the isotropic or the nematic phase at the transition temperature, it often appears in the form of 'batonnets'; these are elongated objects made up of focal conics.

It is obvious that smectic A is more ordered than the nematic, since it has an additional one-dimensional translational order. In compounds which exhibit both smectic A and nematic phases, the former occurs at lower temperatures. Smectic A is characterised by a weak curvature elasticity (for the bending of the layers) as well as a strong crystal-like elasticity (for the compression of the layers). The layers can slide over one another easily, accounting for the fluidity of the phase. The mobility of ionic impurities is greater between the layers rather than normal to them.

Smectic C is a tilted form of smectic A, that is, the molecules are inclined with respect to the layer normal (Fig. 5b). It is somewhat more ordered than smectic A, and occurs at lower temperatures in compounds exhibiting both the states. The tilt angle gradually decreases to zero in such cases as the sample is heated, and there occurs a second-order (continuous) C–A transition which does not involve any latent heat or volume change.

In smectic B, the molecules are upright as in the A phase, but are arranged in a hexagonal close-packed configuration within each layer. Hence, the B phase is more crystal-like compared to either the A or the C phase. At least four other distinct smectic modifications have been identified (D, E, F, etc). We shall not consider them as their precise structures have not been definitely established.

All the above three types of liquid crystals — nematic, cholesteric and smectic — are obtained by heating the crystalline phase, and hence are called *thermotropic* mesophases. Some 5,000 organic compounds are now known to exhibit one or more of

Fig. 6 Focal conic texture of a smectic A liquid crystal, as viewed through a polarising microscope. The diffuse dark lines are projections of hyperbolae and ellipses in the plane of the figure (magnification × 400)

hese phases. The molecules are necessarily long (and have long names); some examples are:

(1) n–p–methoxybenzylidene–p–butylaniline (abbreviated MBBA)

$(CH_3O(C_6H_4)CH : N(C_6H_4)C_4H_9)$

$$\text{solid} \xleftrightarrow{22^\circ C} \text{nematic} \xleftrightarrow{47^\circ C} \text{isotropic}$$

(2) cholesteryl oleyl carbonate

$(C_{27}H_{45}OCOO(CH_2)_8CH : CH(CH_2)_7CH_3)$

$$\text{solid} \xleftrightarrow{<0^\circ C} \text{smectic A} \xleftrightarrow{17^\circ C} \text{cholesteric} \xleftrightarrow{34^\circ C} \text{isotropic}$$

(3) terephthal–bis–4–n–butylaniline

$(C_4H_9(C_6H_4)N : CH(C_6H_4)CH : N(C_6H_4)C_4H_9)$

$$\text{solid} \xleftrightarrow{113^\circ C} \text{smectic B} \xleftrightarrow{144{\cdot}1^\circ C} \text{smectic C} \xleftrightarrow{172{\cdot}5^\circ C} \text{smectic A}$$

$$\text{smectic A} \xleftrightarrow{199{\cdot}6^\circ C} \text{isotropic} \xleftrightarrow{236{\cdot}5^\circ C} \text{nematic}$$

Lyotropic liquid crystals

There is another important group of liquid crystals which are formed by the influence of solvents. These are known as *lyotropic* liquid crystals. The classification of these is somewhat different from that of the thermotropic group. The types of molecular packing in them are illustrated schematically in Fig. 7 for the soap-water system. Soaps are amphiphiles, meaning compounds which have a hydrophilic (an affinity for water) polar group attached to a long hydrophobic (water-repellent) hydrocarbon chain. As the water content is increased, we get respectively the *neat*, *viscous isotropic* and *middle* phases. In the *neat* phase, also known as the *lamellar* phase, the amphiphiles are arranged in layers with their polar heads arranged on flat surfaces and water sandwiched between the flat surfaces (Fig. 7a). The hydrocarbon chains have a more or less disordered configuration. In the *viscous isotropic* phase, the layers are bent in the form of spherical units with the polar heads lying on the surface of the sphere, surrounded by water. Since the spheres are arranged in a (body-centred) cubic lattice, the medium is optically isotropic and is also known as the *cubic* phase. In the *middle* phase, also known as the *hexagonal* phase, the layers are bent in the form of cylinders of indefinite length arranged in a hexagonal array (Fig. 7b).

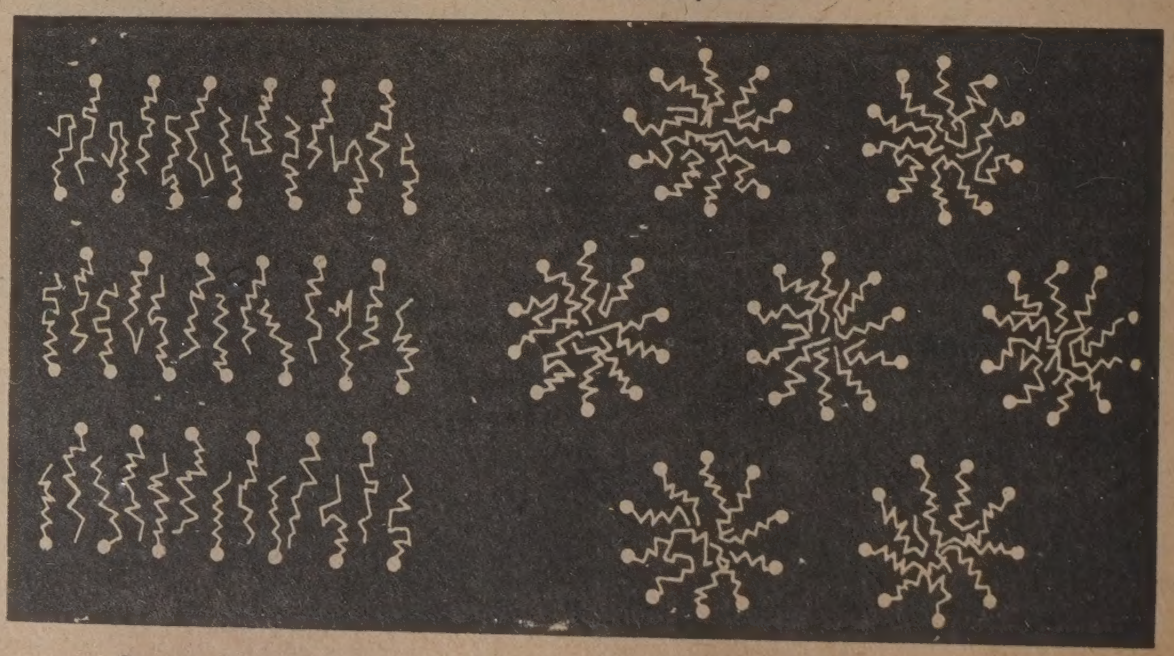
In some systems with a predominantly hydrophobic composition, *inverted middle* and *inverted viscous isotropic* phases can also occur; here the polar heads point inwards with water confined within the units. A precise knowledge of the phase diagram of the soap-water systems is very important to the soap industry. The study of lyotropics has also a future significance, since several biological systems are known to form such mesophases. One example is the bile acid.

Applications

We shall now discuss briefly the physical principles involved in some technological applications of liquid crystals. *Thermography* was, perhaps, the earliest application; the technique was developed in 1965. As already mentioned, the pitch of a cholesteric liquid crystal decreases as the temperature is increased. If the consequent change in the wave-length of reflection spans the visible range between, say temperatures t_1 and t_2, any temperature within these limits can be read off simply by noting the reflected colour. In order to obtain different useful ranges of temperatures, it usually necessary to mix two or m compounds, in different ratios. S tems which exhibit only the chol teric phase between the solid a isotropic phases have a low temper ture sensitivity; approximately, 10°C change in temperature is need to cover the visible range. But those systems which exhibit, in add tion, a smectic A phase at low temperatures, the temperature sens tivity can be greatly enhanced. In t smectic A phase, the twisted co figuration is disallowed since th deformation would tend to chang the layer thickness (see Fig. 5a) wit the consequence that the helic structure rapidly unwinds itself a the cholesteric-smectic A transitio point is approached. In such case temperature sensitivities of the orde of 0·5°C for the entire visible rang are easily achieved.

The simplest method of using th cholesteric liquid crystal for thermo graphic purposes would be to coat layer of the liquid crystal on th blackened surface, whose tempera ture distribution is to be mapped Two problems, however, have to b overcome. One would be the de pendence of the reflected colour or the angle of viewing, and the other the rapid deterioration of the chemi cal due to oxidation. These problems have been solved to some extent by encapsulating tiny droplets of the liquid crystal in a gelatinous base. Fig. 8 shows the thermal mapping of human fingers using such a film. This immediately brings out the possibility of detecting tumours, since the local temperature near a tumour would be different from that at other parts. However, it would be fair to say that it is extremely difficult to make the thermal mapping precisely quantitative. Apart from a slow change in the characteristics of the liquid crystal film itself, it is obvious that the ambient temperature should be very closely controlled

Fig. 7 Schematic diagram of the molecular arrangement in the lamellar or neat (left) and hexagonal or middle (right) lyotropic liquid crystals



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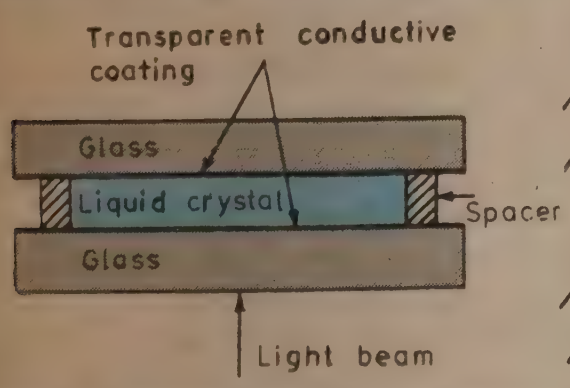
for a successful application of this technique. However, if the required temperature sensitivity is not too high, as in detecting a faulty electronic component or indicating the ambient temperature, liquid crystals are quite handy.

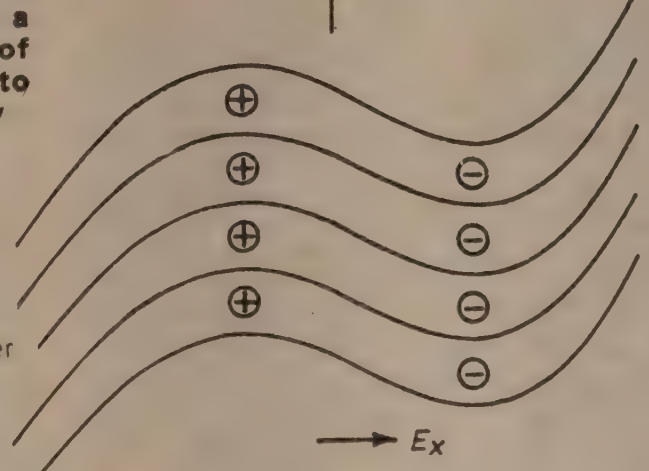
The most important technological application of liquid crystals, however, is in digital display devices. There are several electro-optic effects which can be used for this purpose. The two most important effects are: (*a*) the dynamic scattering mode (DSM) discovered in 1968, and (*b*) the twisted nematic (TN) effect first observed in 1971.

In order to understand the DSM, consider a nematic liquid crystal with negative dielectric anisotropy (like MBBA) and doped with an ionic impurity. The medium is sandwiched between two transparent electrodes with its director parallel to the substrates (Fig. 9a). If a DC or low frequency AC electric field is applied between the electrodes, any

Fig. 8 Thermograph produced when human fingers are in contact with a cholesteric liquid crystal film

Fig. 9 The dynamic scattering effect. A fluctuation of the form shown on the right leads to a charge separation under the influence of an external field, since ions which are attracted by one of the electrodes find it easier to move along the director. Consequently, ions of opposite sign get collected near the crests and troughs of the fluctuation. At a sufficiently large voltage, the action of the external field on the charges leads to a turbulent electro-hydrodynamic flow



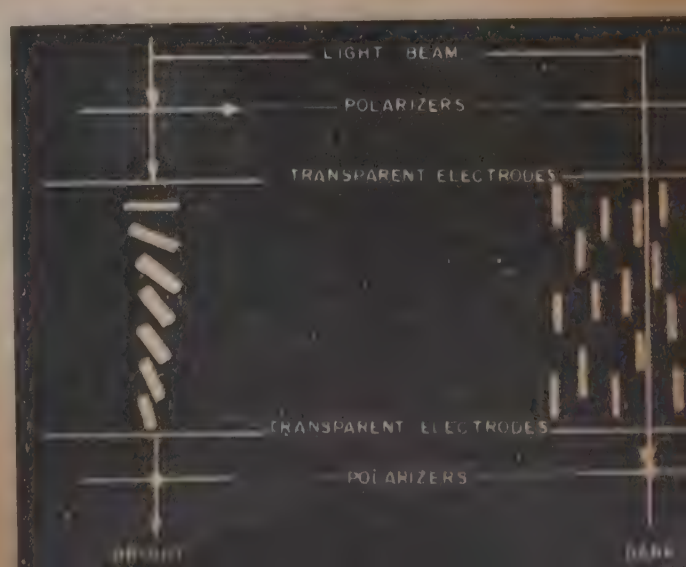


thermal fluctuation in the alignment of the form shown in Fig. 9b gives rise to charge separation because of the anisotropy in the conductivity of the medium. The action of the applied voltage on the space charges gives rise to electrohydrodynamic flow which becomes turbulent at higher voltages. The turbulent, optically anisotropic medium scatters light strongly. This is referred to as the dynamic scattering mode. It is obvious that the effect depends on an interplay between the dielectric and conductivity anisotropies and the elasticity and viscosity of the medium. A typical threshold voltage for the DSM is 15 volts and the current density is $\sim$ 10 microamperes/cm^2. Any character can be made visible by properly patterned electrodes and viewing conditions. However, a drawback is the electrochemical degradation of the material. Unless special care is taken to see that there is no net DC current in the medium, the life of a DSM display can be rather limited.

The TN display is based on the orienting effect of the electric field on a material with strong positive dielectric anisotropy. It does not involve any current flow and, hence, has a very long operating life ($\sim$ 50,000 hrs). By a special treatment of the surfaces of the two conducting glass plates, the director is allowed to twist by 90° between the two plates (Fig. 10a). If a beam of light which is linearly polarised parallel to the director at either end of the TN cell passes through the cell, the plane of polarisation also turns by 90°, because of the strong optical anisotropy of the medium. The emergent beam can now be crossed out by a second polaroid. If now an electric field is applied, the director tends to align normal to the electrodes when the voltage exceeds a certain threshold value. As a consequence, in the bulk of the cell, the medium gets untwisted (Fig. 10b); the plane of polarisation is no longer rotated by 90° and the beam of light is transmitted by the second polaroid. By rotating the second polaroid by 90°, we can get the complementary effect, namely bright field of view in the absence of the applied voltage and dark field of view in its presence. Low threshold voltages can be achieved by suitably engineering the chemicals.

The Raman Research Institute (RRI) has developed processes for the preparation of chemicals of exceptional stability and has produced compositions with a threshold voltage of $\sim$ 1 volt. An advantage is that the low voltage TN display can be driven directly with a low power CMOS circuitry. Further, since it is a pure field effect display, the current drawn is extremely low, about 100 nanoamperes/cm^2 of display area, which makes the TN cell the lowest power-consuming display. On the other hand, a typical light emitting diode (LED) display consumes a power of about 1 watt/cm^2 of display area, which is about 10,000 times higher than that of the TN display. Moreover, the optical contrast between the 'on' and 'off' parts of the liquid crystal displays (LCDs) is

Fig. 10 The twisted nematic display. In the off-state (left), the plane of polarisation of light (moving vertically) rotates by 90° along with the director. In the 'on' state (right), the director is oriented along the applied field and the plane of polarisation is no longer rotated by 90°



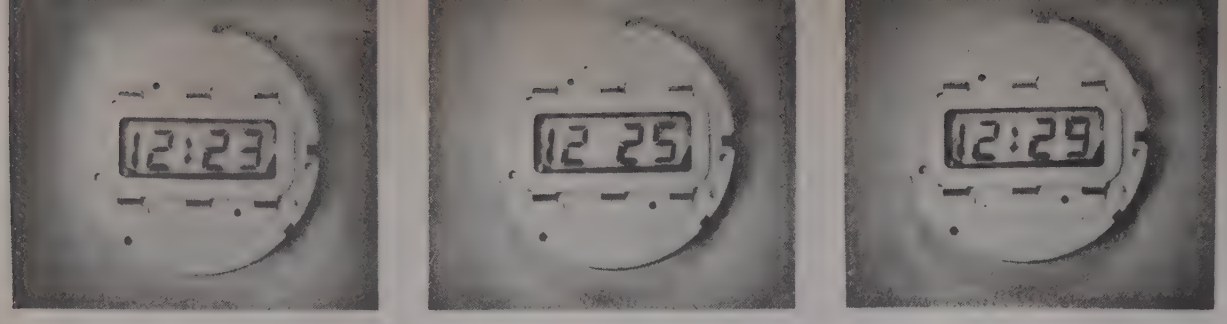


Fig. 11 Engineering model of a watch with a liquid crystal display made at the Bharat Electronics Ltd, Bangalore, in co-operation with the Raman Research Institute. The colon is on for half a second and off for another half a second and, hence, is not visible in the middle photograph

very high. A slight disadvantage of the TN display is that its viewing angle is somewhat limited (about $\pm 45°$ from the normal). For portable gadgets like digital wrist watches, the advantages outweigh this minor disadvantage and the TN display is now being used in more than 50 per cent of all digital watches manufactured. Fig. 11 shows an engineering model using a liquid crystal watch display made at the Bharat Electronics Ltd, Bangalore, in co-operation with RRI. Fig. 12 illustrates some alphabetical characters from a 16-segment alphanumeric display made at RRI.

We shall now mention some other effects which can be used in electro-optic devices: (a) *electrically controlled birefringence:* a pure nematic liquid crystal with negative dielectric anisotropy is ordered with its director normal to the glass plates. Between crossed polaroids, the field of view is dark in the absence of an electric field and is bright beyond a threshold voltage (which is typically 5 volts); (b) *cholesteric-nematic phase change display:* if the cholesteric liquid crystal has a strong positive dielectric anisotropy, there occurs beyond a threshold voltage (typically 80 volts) untwisting of the structure and the medium becomes a nematic. In the 'off' state, the field of view is turbid since the cholesteric usually adopts the focal conic texture (similar to the one shown in Fig. 6 for the smectic), whereas in the 'on' state, it is clear; (c) *storage mode:* if the cholesteric liquid crystal has negative dielectric anisotropy and is conducting because of impurities, we can get the DSM. However, even after the exciting voltage is switched off, the medium retains a turbid appearance, since it adopts the focal conic texture. A high frequency pulse then restores it to the original state.

It is obvious that all LCDs are passive, that is, they do not emit light. Rather, the displayed character is made visible by modifying the ambient light, somewhat like the letters on a printed page or on a transparency. The contrast usually *increases* with the increase in the intensity of the ambient light. This is yet another advantage of LCDs, since self-luminous displays like LEDs tend to give a washed-out appearance under intense ambient light. However, this also means that the LCD cannot be read in a dark room — a tiny external light becomes necessary.

We shall briefly touch upon another important application of LCDs, namely, in graphics. One can think of a set of horizontal (row) electrodes on one plate and a set of vertical (column) electrodes on the other. If we are able to generate the proper electrical signals and operate the display in the multiplexed mode, we shall be able to get a graphic display. However, there are problems in multiplexing LCDs. Since the medium is a liquid, the 'on' and 'off' times of the display are quite slow — in practice, between 10 and 100 milliseconds. As a consequence, direct multiplexing is not feasible. However by using an array of thin film transistors to back each element of the display, scientists at the Hughes Research Laboratories, USA, have demonstrated an operating 5 cm × 5 cm TV using the DSM. If further technological progress makes the technique commercially viable, one may hope to construct a TV screen so thin that it can hang on the wall rather like a framed photograph!

We have by no means exhausted in this short article all the possible applications of liquid crystals. There are, for instance, well-developed academic applications. The structure of anisotropic molecules can be studied by dissolving them in liquid crystals and then studying the spectra (nuclear magnetic resonance, optical, etc) of the oriented solute molecules. Another example is the use of liquid crystals in gas-liquid chromatography. Suffice it to say that research in the area of liquid crystals has been growing rapidly in the past few years.

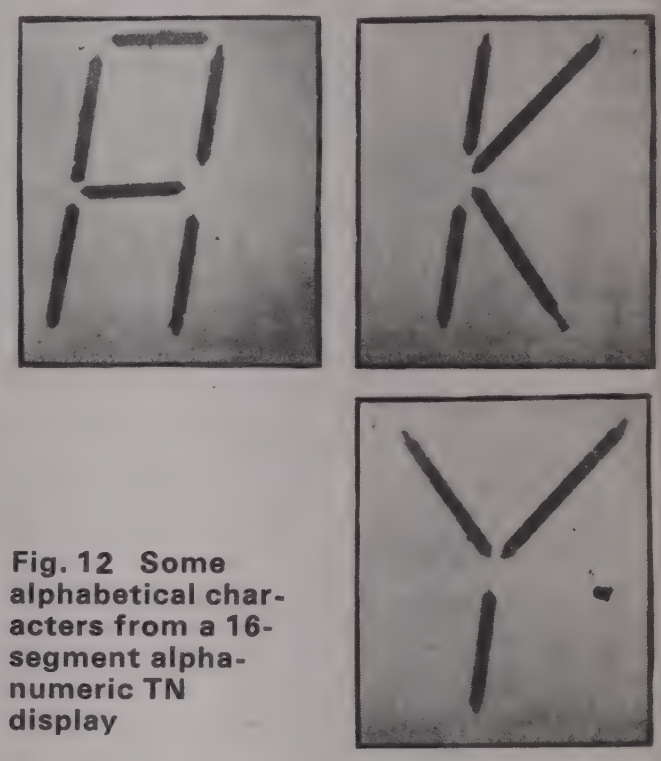
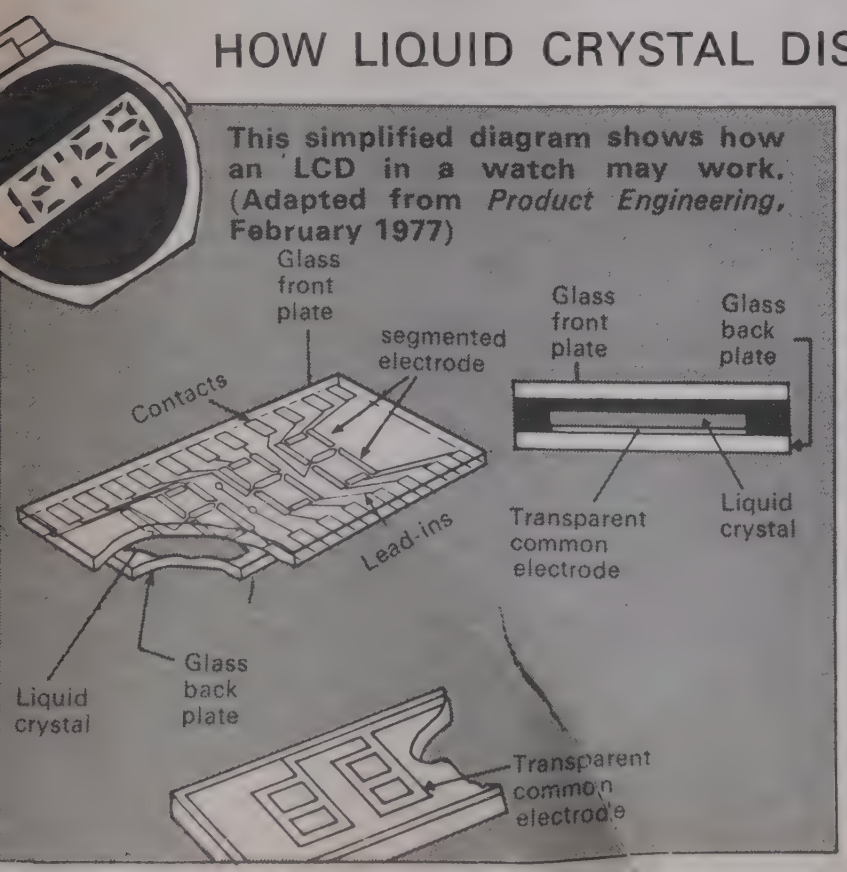


Fig. 12 Some alphabetical characters from a 16-segment alphanumeric TN display

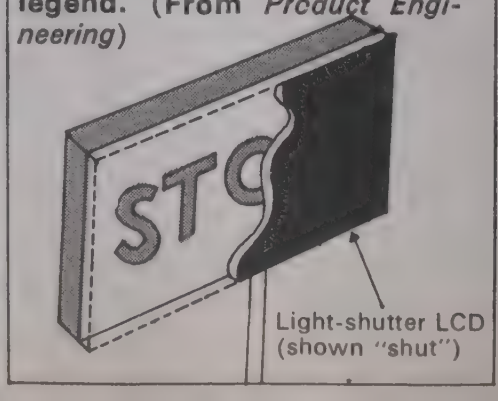
HOW LIQUID CRYSTAL DISPLAYS WORK



This simplified diagram shows how an LCD in a watch may work. (Adapted from *Product Engineering*, February 1977)

THE LIQUID CRYSTAL LIGHT VALVE

In the form shown below, it's a plate covering a legend. In a non-energised state, the plate remains transparent and the legend is visible. When energised by a small electric current, the display turns black and hides the legend. (From *Product Engineering*)



Dr. N. V. Madhusudana (33) is a scientist in the Liquid Crystals Laboratory, Raman Research Institute, Bangalore. He started work in this field with Prof. S. Chandrasekhar several years ago when the subject was still in its infancy and the potential applications of liquid crystals had not yet been discovered. He has about 25 publications in this field to his credit and is also actively participating in the development of liquid crystal devices. *Recommends reading:* **1.** de Gennes, P. G. 1974 *The Physics of Liquid Crystals*, Clarendon Press, Oxford. **2.** Chandrasekhar, S. 1976 Liquid crystals, *Reports on Progress in Physics, Europhysics Journal, 39*, 613–692. **3.** Chandrasekhar, S. 1977 *Liquid Crystals*, Cambridge University Press, Cambridge.

IMMUNOLOGY

Antibodies for Tissue Typing

Reagents containing antibodies to prevent the rejection of tissue transplants such as skin, cornea, bone marrow, kidney, etc and to prevent particular diseases associated with histocompatibility antigens may soon be available off the shelf if a technique developed by a team of British biologists is further refined and commercialised. The team from the MRC Laboratory of Molecular Biology and the ARC Institute of Animal Physiology, both located at Cambridge, UK, has constructed by cell fusion technique a line of hybrid cells capable of producing antibodies against rat major histocompatibility antigens. The details are reported in *Nature* (**266**, 550, 7 April 1977).

Histocompatibility antigens are a class of molecules found on the surface of most cells in the body, providing each individual with a unique molecular fingerprint. Their evolutionary significance is still a matter of debate among immunologists. Besides their role in rejecting transplanted tissues and organs, recent work points to their possible roles in eliminating virus-infected cells and incipient cancer cells and to links with certain diseases.

The British team led by Prof. C. Milstein obtained the hybrid cell lines by fusing mouse myeloma (cancer) cell lines, P3-X63-A$_8$ 8 with spleen cells of AO strain rats previously immunised against DA strain antigens. Polyethylene glycol was used as the fusing agent. Multiple hybrid clones were then grown in individual plates containing about 2 million spleen cells. It was found that of 113 cultures from two independent fusions, 107 contained significant lytic activity against red blood cells and lymphocytes from DA strain donors.

Supernatants from six individual clones found positive for specific immunological activity were tested against target cells of four inbred rat strains, each carrying a different Ag-B haplotype (monotype) including the strain AO. These tests demonstrated that the antigenic target of the clone products (antibodies) is specified by a gene closely linked to the rat major histocompatibility complex (MHC), Ag-B. The team claims it has identified for the first time a uniquely defined antigenic specificity in the rat MHC. They hope that characterisation of the products of other clones will lead to the identification of other specificities of the Ag-B haplotype.

Drs. G. Galfre, S. C. Howe, C. Milstein, G. W. Butcher and J. C. Howard state that their technique offers a very powerful tool for the study of some of the many clinical and biological problems concerned with histocompatibility system that require a reliable and standard supply of anti-histocompatibility antigen antibodies for their solution. The important area of tissue transplantation also depends to a large extent on stocks of reasonable titre monospecific type antibodies against the major histocompatibility antigens, of which there appear to be several hundreds at least. These are at present obtained from immunised volunteers, multiparous women, transplant recipients or primates and take months or years of laborious work to produce, test and become accepted as standard reagents. Their technique offers the possibility of unlimited permanent supplies of standard typing reagents to be available worldwide. They conclude, "the derivation of a rat-mouse hybrid cell line producing antibody against a rat transplantation antigen brings the goal of producing standard permanent supplies of monoclonal antibodies for human tissue typing and other clinical uses one step nearer."

K. A. NEELAKANTAN

ZOOLOGY

Commercial Fishing of Sea Urchins

Sea urchins are a source of food in many Mediterranean countries. Commercial harvesting of sea urchins began in Southern California in 1970 and mainly involves the species *Strangylocentrotus franciscanus*. However, another species *S. purpuratus* co-exists in abundance with the larger *S. franciscanus* in the same rocky areas and feeds on the same seaweed. Dr. M. J. Tegner and Dr. P. K. Dayton of the Scripps Institution of Oceanography, San Diego, California, USA have in *Science* (**196**, 324, 15 April 1977) reported their studies on the developmental behaviour of the juveniles of *S. franciscanus*. They conclude that the commercial harvesting of this species may affect nursery grounds of young urchins and abalones as well as the reproductive potential of exploited populations.

Sea urchins, like starfishes and other related animals, shed their eggs and sperms into the sea where fertilisation takes place. A tiny larva develops and swims to a suitable surface on which it settles to metamorphose into an adult. The American biologists sampled the habitats of both species of sea urchins in an area approximately 1·5 and 2 km off the California shore at depths of 15 to 20 metres in a large stand of giant kelp (*Macrocystis pyrifera*). The microhabitats they sampled included coralline algae (low, turf-forming plants), cobble, kelp holdfasts, the undersides of rocks and under adult urchins, probably the only places offering enough protection for the survival of post-metamorphic urchins.

They found that the juveniles of *S. franciscanus* settle mostly under the spine canopy of the adults. In addition to the small urchins they found under the spine canopy numerous motile organisms including abalones, gastropods, shrimps, crabs, asteroids, ophiuroids and fishes, suggesting that these animals, too, have simply sought the protection of the spine canopy. On the other hand, juveniles of *S. purpuratus* were found to settle equally under rocks or on seaweeds or under other sea urchins. How long do the young seek the protection of the adults? The nursery association apparently lasts till the juveniles are too large (more than 30 to 40 mm in size) to fit among the spines. When the juveniles get larger they move towards the periphery of the spine canopy. The advantages of such an association are that the juveniles have access to the food of the adult besides being protected from predators. Sea urchins are important in the diet of the spring lobster, the senorita and the sheephead.

Drs. Tegner and Dayton confirmed that *S. franciscanus* juveniles seek out the adults of their own species by isolating small areas of rock reefs by surrounding them with sandy siltstones over which the larvae cannot crawl. They removed all adults of *S. franciscanus* from three reefs, but left all sea urchins of the species *S. purpuratus* intact. Four months later, they found 10 juveniles of *S. franciscanus* in the area, one under an adult *S. purpuratus* but the others under an adult *S. franciscanus* that had migrated to the reef after clearance. They also ruled out the possibility that recruitment of juvenile *S. franciscanus* is random with respect to

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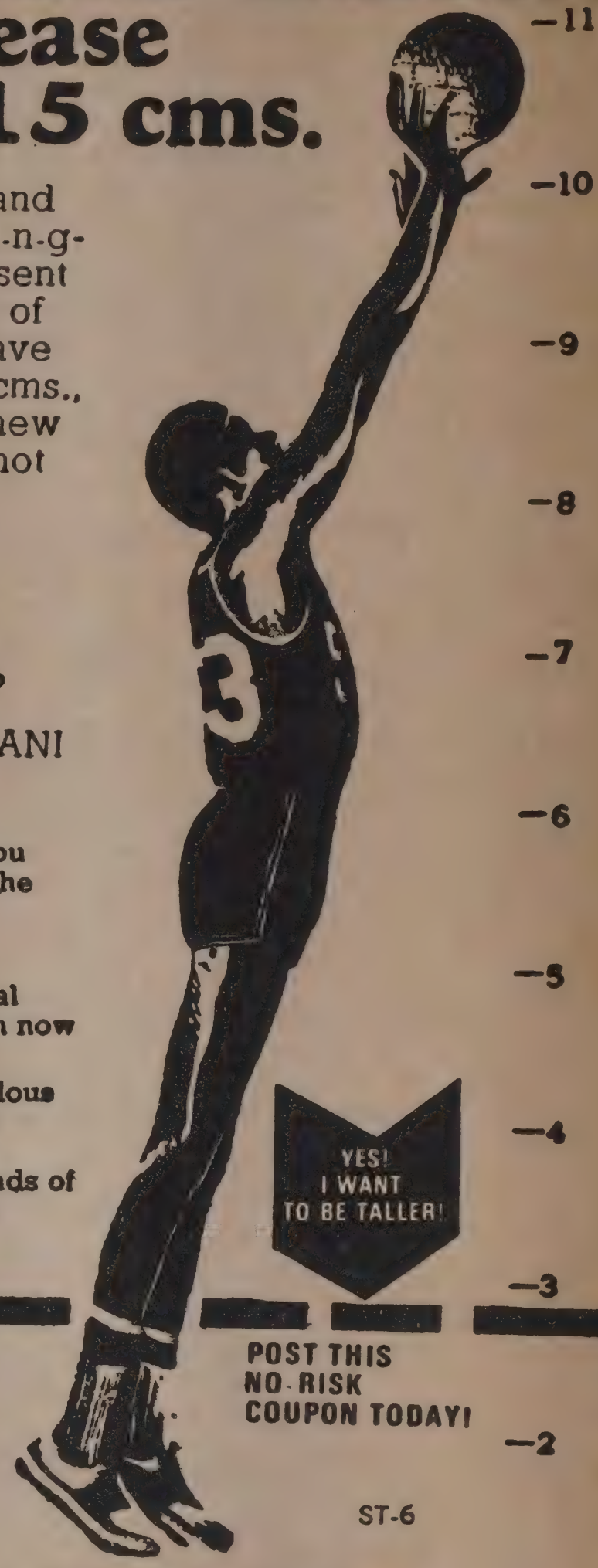

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presence or absence of adults of same species.

The scientists suggest that the cts of continuing commercial fish- will probably be determined by number of adults left behind or number that migrate into an after the harvest is taken. If are deprived of a protective itat through the exploitation of adults, the numbers of sea urchins reaching maturity are likely to decrease. Whether harvesting of *S. franciscanus* will induce a shift in populations, with *S. purpuratus* becoming more numerous, since this species is much more flexible in its choice of habitats at the juvenile stage, remains to be seen.

K.A.N.

RICULTURE

timating Crop Yields Remote Sensing

Remote sensing, particularly via satellites, is now considered a powerful tool to estimate with air degree of accuracy, in a short e, the total land area of a parti- ar crop under vast regions of a ntry. The technique is expected be used by Indian space scientists crop inventory in the country's ond satellite to be launched from Soviet Union next year. The ge area crop inventory experi- nts (LACIE) in the remote sensing llites (Landsats) so far launched, vever, use the measurements of reflected solar radiation only to ntify the crops and to determine amount of land planted under h type of crop. To estimate crop lds, these experiments rely heavily statistical and climatological mo- s based on ground observations. . S. B. Idso, R. J. Reginato, and D. Jackson of the U.S. Water nservation Laboratory, Phoenix, zona, now report in *Nature* (**266**, , 14 April 1977) how the remote sing system can also evaluate crop lds per unit land area.

They planted spring wheat (*Triti- durum* variety produra) in a × 90 m field of loam soil to which rogen fertilisers have been added ore. The field was then divided o six nearly equal north-south ented rectangular plots. Each plot s irrigated with 10–12 cm of ter, five days later. The plots re not irrigated again until 83 days er planting. They were then differ- ially irrigated to obtain six soil ter content regimes.

The amount of incoming and re- cted solar radiation over each plot s measured every 20 minutes by e upright and six inverted pyra- meters located about 50 cm above e top of the crop canopy and the an albedo value for a particular y calculated; the values were rrected for the changing altitude gle of the Sun during the growing ason. In addition, twice weekly, the green leaf area index (the ratio of green leaf area to the area of soil supporting its growth) was measured on three randomly selected plants per plot with an optically integrating area meter. When the heads emerged, three other randomly selected plants from each plot were sampled to determine mean head weight after driving off moisture in an oven. At the end of the growing season, the wheat was hand-harvested from 14-m^2 sections of each of the six plots and every plant was counted to obtain the number per unit area.

They found that the albedo decreased as the season progressed. The decline was initially due to the growth and proliferation of the leaves and finally to the growth and proliferation of the plant heads. A strong linear relationship was observed between both green leaf area index (until day 95) and head dry weight from day 105 to near the end of head growth and the albedo data. There was a large increase in the albedo after the heads started to ripen. The main finding of their study was that final grain yield is a linear function of the minimum albedo reached just before the large increase.

The American scientists state that though ground-based measurements were used as a standard in their experiments, some constant albedo feature such as a dry-lake bed, a rock outcrop, a non-eutrophic lake or even man-made surfaces could be used as a standard in remote sensing. They conclude that measurement of solar radiation is one viable means for the remote sensing of crop yields. Together with estimation techniques based on remote surface temperature measurement, it should make possible a remote sensing system for the evaluation of agricultural productivity on a global scale.

K.A.N.

OPTICS

Free Electron Laser

Physicists have long dreamt of a laser tunable over a wide band of frequencies. The laser action depends on the excitation of electrons in an atomic or molecular medium. Hence, the beams they give out are limited to one or, at most, a few discrete frequencies corresponding to the quantum jumps permitted by the orbital structure of the atom or molecule.

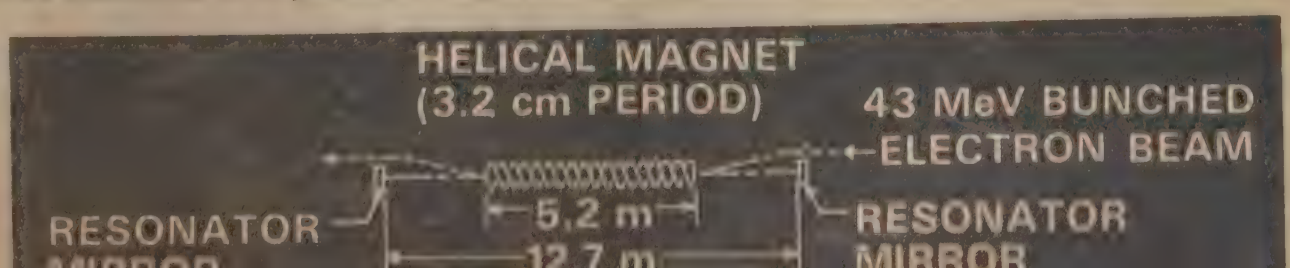
It has been theorised that a laser based on free electrons as the lasing substance can overcome the above difficulty. A group of six physicists from the Stanford University High Energy Physics Laboratory, led by Dr. J. M. J. Madey has reported the first operation of such a free-electron laser in the *Physical Review Letters* (**38**, 18 April 1977).

Their technique consisted of passing a beam of energetic electrons from an accelerator through a spatially periodic transverse magnetic field. The field causes the electrons to emit synchrotron radiation which, in turn, stimulates coherent emissions and laser type amplification. In their reported experiments, a 43 MeV electron beam from Stanford's superconducting accelerator was passed through a field of 2·4 kilogauss generated by a superconducting magnet coil. The result was coherent radiation in the infrared region at a wavelength of 3·417 microns, with a power gain by a factor of 100 million over the random unstimulated emission from the electrons.

The wavelength of emission is known to vary inversely as the square of the energy of the electrons. Since accelerators can give electrons of a wide range of energies, the Stanford team states that their experiments, in principle at least, can lead to a type of laser, that would be tunable over a wide range of the spectrum from infrared through the visible down to 1,200 Å in the ultraviolet. However, since gain falls off at short wavelengths — it depends on the 3/2 power—much stronger electron currents would be required to produce worthwhile power at short wavelengths.

A. V. SAPRE

Free electrons in a periodic magnetic field produce laser amplification in infra-red



THE JUMPING GENES

It is by now well-established that the genetic material DNA in the chromosomes governs the initiation, regulation and maintenance of the protein synthesis in the body. The DNA molecule is functionally so divided that there are three distinct regions, each concerned with one of the above three mechanisms. A gene is that part of the DNA molecule which specifies the synthesis of a single poly-peptide chain (protein). There are three different types of genes called structural genes, operator genes and regulator genes. These genes have been considered as static entities for a very long time. It was presumed that a gene may move or lose its function only under abnormal conditions such as a mutation which can alter the nucleotide sequence of DNA molecules. Recombination is another condition which involves exchange of segments between DNA molecules.

Evidences have, however, been accumulated in recent years in favour of the movement of genetic structures. It has been found that in bacteria the genes and segments of DNA move on to and off the chromosomes and move from place to place on chromosomes with frequencies as great as 10^{-2}. Similar phenomena probably occur in higher organisms, too. The fact that genes move in and about chromosomes is now termed "jumping genes". Jumping genes are a common occurrence in cells. Various segments of bacterial DNA have been observed by a number of investigators to move freely from place to place on and among the chromosomes, in viruses, and in plasmids (small pieces of extra-chromosomal DNA that replicate independently and can be directly transferred from bacterium to bacterium).

How is the movement of the genetic material detected? It has been achieved in two independent ways. First, the movements of short segments of DNA, about the size of genes, were noticed in 1968. These could prevent the subsequent expression of whole blocks of genes and control the expression of the genes at the site to which they move (insertion elements). Second, within the last two years, large segments of DNA-containing genes, which confer resistance to antibiotics and which can also turn off gene expression, were found to move (antibiotic resistance elements). These segments have been found to jump from plasmid to plasmid and more so from plasmid to virus to bacterial DNA. These two types of movable DNA segments (insertion elements and antibiotic resistance elements) have been found to have many structural similarities. What is more, at both ends of several resistance elements are found identical copies of insertion elements. These are thought to be necessary for the movement of the resistance elements. Those antibiotic resistance elements that do not contain copies of insertion elements have instead at either end repeated sequences of DNA which seem to be necessary for their movement.

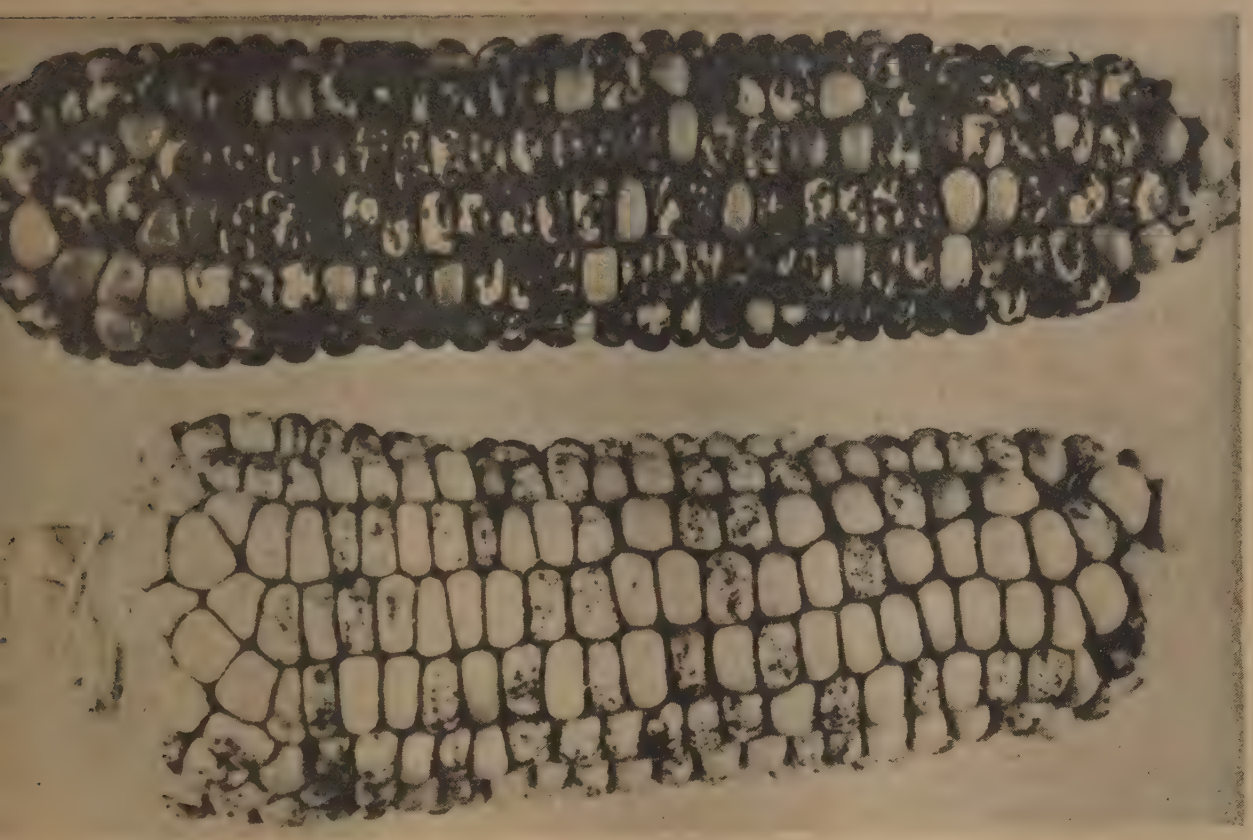
Norman Davidson and his associates at the California Institute of Technology found that the insertion elements play a critical role in chromosomal gene transfer during bacterial mating. The repeated sequences at the ends of antibiotic resistance elements seem to define the regions where these elements interact with plasmids, viruses and bacterial chromosomes. Now, molecular biologists are of the opinion that regions bound by both insertion sequences and repeated sequences of nucleotides at the ends of antibiotic resistance elements can replicate independent of other gene sequences. This may lead to a spread of antibiotic resistance gene, enabling bacteria to become resistant to antibiotics and thus enhancing their pathogenicity. The pathogenic resistance may be transferred from bacterium to bacterium by way of plasmids and viruses.

Many investigators now find that both insertion and resistance elements in addition to turning off may as well turn on gene expression, thus enabling these segments of DNA to act as regulatory switches. What is meant by the antibiotic resistance element prevents gene expression only when it is at a particular orientation. It actually mutates the gene in which it is inserted and may even turn on gene expression in the adjacent genes. The insertion elements, when prevented from inhibiting gene expression, turn on the expression of adjacent genes.

Evidence that similar phenomena may occur in higher organisms is of two types: structural and genetic. The structural evidence consists of similarities between the orientations of various sequences in eukaryotic DNA and the orientation of sequences on either end of the antibiotic resistance elements of bacteria. Single strands of eukaryotic DNA separated from double strands form numerous stem and loop structures that resemble structures formed by bacterial DNA containing antibiotic resistance elements. The DNA of eukaryotic cells has, in fact, been found to contain many regions that can form stem and loop structures. Such structures are formed in bacteria from antibiotic resistance elements since the identical end sequences of these elements are oriented in opposite directions.

The genetic evidence is that in lower organisms like *Drosophila*, the chromosomal segments sometimes undergo unusual deletions and rearrangements. But, there is no direct genetic evidence that the moving segments of eukaryote DNA resemble those of moving bacterial DNA. Drosophila genes have also been reported to move, in addition to undergoing deletion. Barbara McClintock of Cold Spring Harbor Laboratory in New York says that the moving segments of DNA in corns, which she calls "controlling elements", are the best evidence that DNA segments move about in higher organisms. The moving segment controls the expression of a gene by integration with them; they may subsequently leave that site restoring the activity of the gene and get integrated elsewhere. The controlling elements may turn on gene activity and may bring the expression of adjacent genes under its regulation.

The above possible roles of moving segments of DNA suggest that they may play an important role in the development of cells and their transformation by viruses. By virtue of the ability of these elements to shut off gene expression in differentiated cells of higher organisms, and stimulate the expression of genes transcribed only under special circumstances,



Two maize ears showing differences in expression of a gene required for anthocyanin pigment formation. Each kernel reflects the action of a two-element control system, both elements being potentially movable. One element resides at the locus of the gene and modulates its action, while the second element resides elsewhere. The former responds to the second element only when it is active. On each ear, the kernels with variegated patterns exhibit this interaction. When the second element is inactive, the gene-associated element causes the exhibition of faintly pigmented kernels on the ear to the right and by the uniformly more darkly pigmented kernels on the left. The presence and action of such movable elements may be responsible for the very rapid development of the maize plant as we know it today and for its large number of highly distinctive races.

(*Photo courtesy :* B. McClintock)

ey may be related to the mechanisms which viruses transform normal lls into tumour cells. In fact, the NAs of many viruses that integrate to chromosomes of higher organisms ntain at their ends repeated nucleode sequences with opposite orientaons. Hence, they could mimic the acterial insertion elements or antiotic resistance elements that can rn off or on the host genes.

What is the mechasm by which the gene expression is rned off? Sankar Adhya, Donald ourt, Asis Das and their associates t the National Cancer Institute propse that the insertion elements conin a sequence recognised by a rotein called rho, that terminates ene transcription. So gene transription cannot start again until a ew initiation signal is received. hese initiation signals occur at the eginnings of the blocks of genes ontrolled in concert. Thus, transription would stop in the interior of hat gene where the insertion element incorporated and no subsequent enes controlled by the inserted gene would be expressed. However, the nechanism as to how the insertion nd resistance elements integrate into DNA is still open to investigation. One suggestion is that the antibiotic resistance element codes the synthesis of an enzyme that can recognise the inverted nucleotide sequence at the ends of the element. The enzyme then would join up the end sequences with bacterial, virus or plasmid DNA sequences and catalyse the insertion of the antibiotic resistance element.

Further, it has been found that there are three segments of the antibiotic resistance element, namely, two end sequences and a middle segment. Only when the outer two segments are present can the insertion of the resistance element occur, and the middle segment contains a gene whose product is necessary for insertion. There is at present, no doubt, that the movements of the genetic material, DNA, the insertion elements, and the antibiotic resistance elements provide an interesting and intriguing field for molecular biologists to work on. We have, however, to wait for a full understanding as to how these jumping genes jump and what the jumps signify.

V. SRITHARAN

[Mr. Sritharan is a post-graduate student in the Biochemistry Department of Jawaharlal Institute of Post-graduate Medical Education and Research, Pondicherry.]

IN LIGHTER MOMENTS

The young Ernst Rutherford knew well that it was a tough job for a colonial New Zealander like him to get accepted as a research scholar at the Cavendish Laboratory in Britain, then headed by a very able and hard taskmaster, J. J. Thomson. But he had high hopes because of his remarkable work on electromagnetism. In the end, the final choice was between Ernst and one J. C. Maclaurin, a chemist. Ernst lost, and had to go back to his village to look after his family farm from where he wrote to his fiancee: " Gold has won " Maclaurin's only qualification was that he had published a small book, *The Treatment of Gold*. However, some time later Maclaurin got a local job and declined to go to England, and Ernst was selected.

* * *

How the quarrelsome Isaac Newton could get on with his extraordinarily beautiful, witty and extrovert niece throughout his life without a single row was a mystery. Even Voltaire dittoed the rumours that Newton exploited or, at least, utilised her for " the furtherance of his ambition ". The philosopher is on record: " When I was a young man, I used to imagine that the Court and the City of London had named Isaac Newton ' Master of the Mint ' by acclamation. But I was wrong. He had a most charming niece . . . . She greatly pleased the Chancellor of the Exchequer . . . . The infinitesimal calculus and gravitation would have been of no assistance to Newton without a pretty niece."

* * *

The pure mathematician, G. H. Hardy, was always a perfect disbeliever. Even during his student days he refused to enter college chapels. Not that he had no religious and clerical friends; he had, but " God was his personal enemy ". Once, when he was enjoying the morning play of a cricket match at Lord's, the sun was brightly shining over the pavilion and a batsman felt dazzled by a bright reflected light from somewhere. On his complaint, the umpires, the linesmen and the organisers of the match ran all over to locate where the reflection came from. And when it was discovered to be coming from a large ornamental cross hanging on the broad chest of a clergyman, he was requested by the umpire to remove it. Sitting quite close to him, Hardy was so much delighted at the clergyman taking the cross off, that as soon as the umpire whistled for the lunch, he began writing cards to his clerical friends informing them of the sad plight of their ' reverend father '.

S. N. MUNSHI

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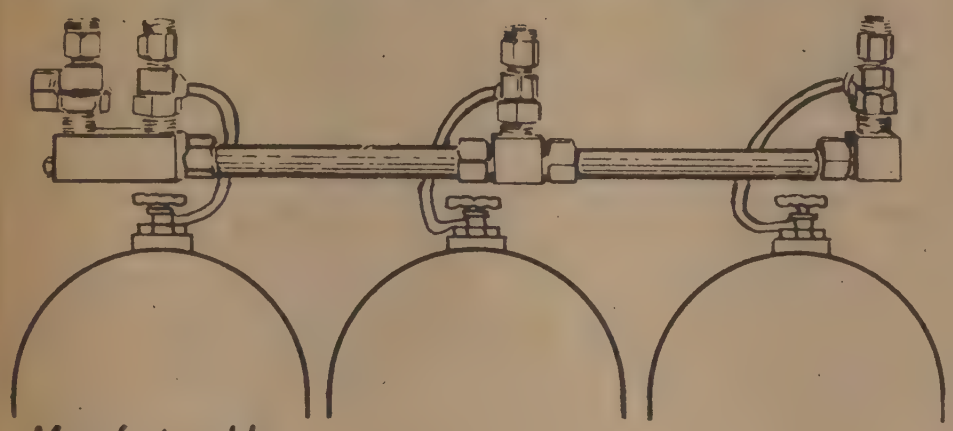

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The 500-year-old banyan tree at Adyar in Madras. It has over a hundred root-stems (Photo: D. I. Chanthamian)

ET'S GET TO KNOW OUR TREES!

The Fig Family

While the name "fig" conjures up the vision of a sweet, juicy, greenish-purple table fruit to t of us, the word (derived from *us* in Latin) represents to the bota-ally-minded a genus of plants ch share some very peculiar tures.

There are about 600 species of *us* in the world of which about 65 ur in India. This large assemblage plants includes large trees, shrubs l even slender and creeping climb- plants (for example, the wall-eping *Ficus pumilla*) and is widely ributed in the tropics. All plants this genus have entire undivided ves and exude a milky latex from ised parts of the stems. The singu-y characteristic feature common all, however, is the unusual and eresting manner in which the wers are arranged. Instead of being osed in a cluster on a single stalk, flowers are arranged side-by-side, ost crowded together, on the er wall of a flask-like fleshy struc-e known as the receptacle.

The structure which looks more a miniature fruit (a small fig, in t) than an aggregation of flowers a small pore-like opening at the l — much like the opening of a bular purse closed with a purse ing. The minute flowers inside are isexual, either only male or female, d do not possess a differentiated lyx or corolla. The male flowers located close to the opening of receptacle while the female flowers of two kinds — one type which fertile with long styles (and, there-e, capable of bearing viable seeds), d the other barren female flowers th short styles and empty ovaries alled gall flowers).

All three kinds of flowers may be borne inside the same receptacle, or separately, for example, male and gall flowers in one and fertile female flowers in another.

Evidently, the hidden nature of the fig flowers would make pollination difficult since neither the wind nor the usual complement of large insects, like bees and butterflies, would be able to help. During countless million years of evolution, however, a remarkable give-and-take (symbiosis) has developed between the fig species and certain small-winged insects (*Blastophaga*) which are solely responsible for successful pollination. These insects, commonly called fig insects, are only about two millimetres long and belong to the same order as the ants, bees and wasps (Hymenoptera).

The female insect enters the receptacle through the pore and lays its eggs in the ovary of the gall flowers which then grow and hollow out into a shell-like structure as the larvae develop. In fact, the insect attempts to deposit its eggs into fertile flowers as well as gall flowers but the long styles of the former prevent this and in the bargain are pollinated by the pollen the visitor has transported from other flowers; the eggs can be laid only in the short-styled gall flowers. An interesting exercise for the inquiring person would be to cut a fallen wild fig into two vertical halves and observe with a handlens the transparent-bodied larvae feeding inside and sometimes, with luck, even the dark-bodied little wasps emerging and grooming themselves. The fig, therefore, is both a breeding place and a larder for the fig insects!

When fully developed and ripe, the fig "fruit" is really the greatly enlarged receptacle and the true fruits (to the botanist) are the many small pinhead-sized, hard, one-seeded things embedded inside.

The poet Henry Van Dyke described the tree as having arisen "*from a wrinkled seed in a earth-bound clod,/An arch, a column in the temple of God*". In the Indian setting, a tree of such magnificent proportions as to be a veritable monument is the ancient **banyan** (*Ficus bengalensis*) (*bad* in Hindi). It often begins its growth in a crevice in a wall or bark of a tree, and as it grows, surrounds and grips the substratum. The many outgrowths from the stem reach down to the ground and serve as additional roots (aerial roots), and often join with one another forming a thick mass of interlacing stems which gradually crush the life out of the original tree which gave it support.

Such growing figs (epiphytes) are often referred to popularly as "strang-

Figs cut and seen through a lens

ler figs". In large trees, the aerial roots arise from the thick side-branches and give extra support and nourishment to the tree thus allowing it to grow further and spread laterally. Many roots grow down the main trunk and merge with it in the course of time to increase its thickness; the general appearance of the trunk

sometimes is that of a sculpture in relief. The banyan figs are usually seen from January to May, are about two centimetres in diameter, red and globular, and grow in pairs in the angles of the leaves. These fruits are not palatable to man but are a favourite with many birds, bats, monkeys and squirrels.

The common name of the banyan is believed to have been derived from the fact that traders (*banias*) in olden times used to sell their wares in markets held in the shade of this tree.

The banyan has few economic uses owing to the rather porous quality of the wood; the leaves are used as fodder for livestock sometimes. To the Hindus, the tree has a religious significance. The *Chaturmas Mahatmya* mentions that god Brahma was transformed into this tree; the dry twigs are used as *samidhas* to produce sacred fire; the leaves are one of the components of the five sacred leaves (*panch pallava*). On Jestha Shudh day, women are advised, in the *Vratraj*, to worship the tree, as did Savitri who got her deceased husband back.

In the indigenous system of medicine, the bark is used in diabetes, and Indian investigators have found that it lowers blood sugar level in experimental animals.

An interesting but rather uncommon variety is known as Krishna's buttercup (*F. bengalensis* var. *krishnae*) in which the base of every leaf is folded and joined to the leaf stalk making it look like, and also usable as, a cup.

The largest known banyan tree is in the Indian Botanical Garden, Calcutta, which has over 300 thick aerial roots (now really thick trunks in their own right) and a continuous spreading canopy over 300 metres in circumference (Photo: B. K. Singh)

The **pipal** (also spelt as 'peepal' or 'peepul') tree (*Ficus religiosa*) too, begins life as an epiphyte seeking support but not nourishment from other trees. Unlike the banyan, the pipal does not have prominent aerial roots, and also does not spread out. The leaves are almost as large as those of the banyan but are heart-shaped (cordate) with a smoother surface and the tip drawn out into a long point. The leaf stalk, too, is longer, and in its axils the small fruits appear in pairs — green at first and dark purple when ripe. The tree is deciduous and the leaves drop off in mid-winter. New leaves, which appear in April, are light red in colour, turning pink and later green as they mature.

The pipal is sacred to both Hindus and Buddhists. In Hindu mythology, the tree is considered a transformation of the guru of the gods, Ashwatha, and is, therefore, believed to be frequented by them; religious ritual, therefore, enjoins that the tree should be watered, worshipped and circumambulations (*pradakshina*) performed. Like the banyan, pipal twigs also serve as kindlings for the sacred fire and the leaves are used for pouring libations, and as *panch-pallava*. To Buddhists, the tree, called the 'Bo' tree, is of special significance as it was under this tree that Gautama Buddha attained enlightenment in the 6th century BC. Pipal leaves make a rich fodder for livestock as their protein content is higher than that of grasses.

Both the banyan and pipal are popular roadside trees but the convenient method of propagation is different for each — the banyan takes well from cuttings whereas the pipal is propagated better from seeds.

In the hilly regions of Western India, one may come across a small pale-stemmed tree which looks like a rugged and miniature replica of the pipal growing on rocks; this is the **pair** tree (*Ficus arnottiana*). It has small purple fruits spotted with greenish dots when ripe. One of the most handsome of the fig trees is the **India rubber tree** (*Ficus elastica*) which, in its natural habitat of the forests of eastern and north-eastern India, attains a height of over a hundred feet (30 metres). Its smooth greenish bark, buttressed bole and evergreen canopy of large shining elliptical leaves make it a desirable ornamental and shade tree in many gardens and parks. Its leaves are a rich dark green in colour and the fresh buds appear as delicate pink finger-like structures.

To some of us, especially the city troglodytes, the India-rubber tree is familiar as a beautiful young potted plant used as a room decorator.

Sharing the natural habitat with the India rubber tree is a big evergreen fig tree with conspicuous bright golden yellow fruits; this is the **golden fig** (*Ficus benjamina*). It has few aerial roots and a dense evergreen canopy of small leaves resembling those of the India rubber tree. The leaves are dull green and

An epiphyte will seek support anywhere like this arch-growing pipal near Dehra Dun (Photo: R. K. Goyal)

Pipal leaves

athery. It is sometimes planted as a oadside tree for its shade and beauti- l fruits — inedible though, but of riking beauty — like drops of liquid old liberally sprinkled on a back- round of verdant foliage.

To those who love o amble by rivers and streams, ne **gular** or **umber** (*Ficus glomerata*) perhaps a familiar tree. What sets apart from most other fig trees is he occurrence of its large red pear- haped receptacles (fruits) in bunches rising from the main trunk and hick side-branches during the sum- ner months. The fig is fragrant, weet and very succulent but not palatable to man.

A number of legends are associated with this tree. The *Gurucharitra* states hat the umber is the abode of god Dattatreya. The *Chaturmas Mahatmya* mentions the transformation of *Shukra*, eacher of the demons, into an umber ree. Also, the fourth incarnation of Vishnu, the lion-bodied Narasimha, is said to have dug his claws into the bark of this tree to rid himself of Hiranyakashyapu's poison after he had killed the demon.

A rather small tree with very rough sandpaper-like leaves is the **bokeda** or **hispid fig** (*Ficus hispida*). It is also the only fig tree to have opposite leaves. This tree reproduces very quickly; when young it resem- bles a shrub, and has assumed weed proportions in vacant lots, along road and rail culverts and moist dumps. Its green fruits turn pink on ripening and, like those of the umber, grow in clusters on the stem. The seeds cause vomiting and purging; the milky juice is used in indigenous systems of medicine; its bark yields a coarse fibre.

Two 'strangler figs' in Bombay's Borivli National Park (Photo: S. N. Kulkarni)

From the economic and nutritional standpoint, the most important fig is the common edible fig (*Ficus carica*). This native of Carica in Asia Minor, extensively cultivated in many parts of the world, and in the drier parts of India, does not require pollination by the fig insects for fruit matura- tion; it, therefore, has no seeds in- side, only hollow seed coats, and is described as parthenocarpic. A few horticultural varieties are known; two other important ones are: the **wild capri fig** — the progenitor of all cultivated types but itself inedible, and the **Smyrna fig.**

The Smyrna fig fruits only after pollination by the capri fig insect. The process by which this is brought about is known as "caprification", that is, growing the wild fig side-by- side with the cultivated variety, or artificially, by means of a fine glass rod drawn to a point and inserted first into the wild fig and then into the cultivar.

While the scientific explanation for caprification is common knowledge today, the need of the wild fig for successful fruiting was empirically observed by the Egyptians over 3,500 years ago. A ritual concerning this has been depicted on some monu- ments of ancient Egypt: when culti- vated figs flowered, men carried in flowering branches of the wild capri fig and tied them to the trees! Aris- totle (300 BC) was also aware of this phenomenon.

The next time you eat a fig, it may be worth remembering that this fruit, besides the high sugar content, has the highest calcium and iron con- centration compared to other plant sources, and is also a good laxative to boot.

S. R. AMLADI

Golden fig

Bokeda

Gular

SUSHMA

# of those deadly denizens of the seas

venoms

S. S. BHATTACHARYA

In the legends, Shiva has a name Neelkanth — the "blue-throated" — because he had held in his throat the venom from the snake-king's mouth as the gods and the demons churned the sea in search of the nectar of immortality. Man is denied this immunity from venoms and poisons — be they from the creatures that lurk in the waters or on the soil, or even plants that grow on that soil.

While the chemistry of many venoms and toxins is still undeciphered, scientists have been able to identify the sources of many and their effects on man. In these pages, experts provide a glimpse of that knowledge . . .

Not many are aware that some jelly fish stings can kill a man in less than a minute. And that the stings of marine snails, sting rays, scorpion fishes, and sea snake bites can be fatal.

Several marine animals are, in fact, venomous. And since man is turning more to the sea in search of food, fuel and minerals, it may well be helpful to know these creatures, and explore the sea without endangering human lives. For, even the diver's suit may not fully protect an underwater explorer against these animals.

Jacques-Yves Costeau, the renowned ocean explorer, narrates an interesting incident in his book *World Without Sun*. The men and the divers in the underwater vessel "Conshelf" had developed itches and swelling in their ears. The reason: "The water was suffused with almost invisible colonies of tiny gelatinous siphonophores, capable of delivering painful venomous stings. This nasty little creature was stabbing a microfraction of an inch into the exposed portions of the oceanauts' bodies, usually the lips or the ears." Only one diver had no trouble — he had earwax, a result of not washing often in an attempt to save fresh water, and it acted as a protective shield. It was considered "a milestone in diving medicine".

Beneath its surface, the sea seethes with life. Marine animals are extremely diverse — in form and in their mode of life. They are found in different parts of the sea. Accordingly, they are divided into littoral, those living on the shores of the intertidal zones; pelagic, swim-

ng or floating forms which occur
m the surface of the sea to a depth
about 150 metres; benthic, the deep
forms; and abyssal forms or the
ttom-dwellers.

In all these environments, the
imals face the eternal struggle for
stence. They are, therefore, vari-
sly modified to compete with the
ner inhabitants of the same habitat,
ainly for food, shelter and self-pro-
ction. Some of the animals deve-
ped a hard calcareous shell (Mollu-
, Anthropoda, etc) or a hard cal-
reous encasement (corals) for pro-
ction; some started living in bur
ws, tubes or under stones (Anne-
a, Mollusca, etc) to hide from
edators, while some became fast
immers either to catch prey or to
e from enemies (octopus, shark,
c). Yet others have bodies shaped
match the environment, or change
lours in accordance with the back-
ound; this enabled them to conceal
emselves from enemies or to catch
ey without being noticed. There are
veral other forms of modifications.

It is most likely that the develop-
ent of the poisonous substance or
otoxin ('bios' means life) within the
dy of some of these animals is
nother form of modification for
ffence and defence. But the bio-
gical significance of the marine bio-
xin has not been fully understood.

There are two categories of animals
hich produce biotoxins — poisonous
nd venomous. While animals which
evelop toxins in any part of the body
nd are poisonous to eat are called
oisonous, those which inject venom
y means of a venom apparatus are
enomous. Thus, all poisonous ani-
nals are not venomous. This article
eals with venomous animals that live
the sea.

The marine invertebrates (animals
ithout backbone) so far reported as
enomous are coelenterates (hydroids,
lly fishes, sea anemones and corals),
few annelids (sea mouse, bristle
orm), some of the molluscan animals
marine snails, *Conus*, cuttle fish,
ctopus and squid) and echinoderms
tar fish, brittle star and sea urchin).
Nemertine worms (Phylum, Rhyncho-
oela) have also been reported to be
enomous, but the venom apparatus
n them has not yet been fully estab-
ished. Among marine vertebrates
animals with backbone), many fishes
nd sea snakes are venomous.

Studies on the chemical and phar-
nacological properties of these ven
oms may help us in developing
useful antitoxins which can save
uman lives. Highly active biotoxins
re also used as molecular probes in
neurophysiological research. The bio-
toxin, thus, may be useful in explain-
ing the nature of both the nervous
and muscular functions.

Knowledge of marine biotoxins is
essential in military operations, too.
Indeed, the need for an exhaustive
review of all the fields of biotoxico-
logy became obvious to American
defence scientists after the biotoxic
experiences encountered by American
troops during World War II. Prompt-
ly, they initiated a research pro-
ject. Research on the morphology of
venom apparatus, nature of the bio-
toxin, mechanism of intoxication, and
various medical aspects of the sting
such as clinical characteristics, pa-
thology and treatment has been
carried out in the USA, Russia,
Japan, Australia, the UK and a few
other countries. Unfortunately, despite
India's long coastline and the wide-
spread occurrence of marine venо-
mous and poisonous animals, hardly
any importance has been given to
this field in this country.

(Above) ***Pennaria*** **(stinging hydroid)**

(Below) ***Lytocarpus*** **(stinging hydroid). Sting from this hydroid is very painful and more serious than other tree-like branching colonial coelenterate animals**

Venomous marine invertebrates

The coelenterates are the simplest form of marine animals to develop the venom apparatus. These are either sedentary or attached to rocks or any sub-stratum, occurring in the intertidal zone to depths of 1,000 metres or more, or planktonic (floating), or free-swimming forms distributed from shallow waters to the open sea. Coelenterates are polymorphic; they exhibit various forms. There are, however, two main forms — an elongated, sessile-type polyp and a free-swimming, umbrella-shaped medusa. What distinguishes this group from others is the presence of long, thread-like tentacles equipped with poison-containing, stinging cells or nematocysts (see box on p. 32).

Hydroids, which have tree-like branching forms, and sea anemones or corals are sedentary (fixed) coelenterates. Hydroid colonies are found attached to rocks, seaweeds, etc. The sting of most of the hydroids is not felt by man. Genera such as *Lytocarpus*, *Pennaria*, *Aglaophenia* and *Halecium* have been reported to sting humans. Of these, the first two are common on Indian shores. *Lytocarpus* forms a feather-like colony in the shallow rocky shores and grows to about 100 to 200 mm in height. *Pennaria*, which grows to about 50 to 100 mm, forms a somewhat lace-like colony in the rocky shore.

Though commonly called sea flowers, sea anemones can sting humans. They are found in all the seas from the intertidal zone to depths of 5,400 metres or more. Corals are usually small sea anemone-like polyps enclosed in stony calcareous cups (see SCIENCE TODAY, June 1976). They are mostly colonial and are restricted to depths of about 45 metres in the tropical waters, though a few species occur in temperate waters.

S. N. KULKARNI

B. F. CHHAPGAR

(Left) *Paracondylactis indicus* **(sea anemone). This sea anemone, common in the mud puddles in Bombay shores, grows to 60 to 500 mm in length. The colour is reddish-orange with white tentacles. The sting of this sea anemone is felt by man. (Right)** *Plotosus lineatus* **(cat fish). These are elongated eel-like fishes found in coastal waters of the Indo-Pacific area. The dorsal and pectoral fins have serrated spines**

In India, they are found in the Andaman and Nicobar Islands, Lakshadweep, in Dwarka and Okha in the Gulf of Kutch and at Rameswaram in Tamil Nadu. Some of the species of corals belonging to *Astreopora* (stony coral), *Acropora* (elk horn coral), *Goniopora* (stony coral), *Millepora* (stinging coral) and a few others have been reported to sting humans.

Among the planktonic (floating) and free-swimming coelenterates capable of stinging humans are siphonophores (eg, *Physalia*) and small and large jelly fishes. *Physalia*, commonly called the Portuguese-man-of war, or the blue-bottle (because of its bluish green, bottle-like float above the water; see figure on p. 31), is distributed worldwide. It varies considerably in size and colour. It may grow to a large size with a float 10 to 30 cm long and tentacles measuring two to three metres, or even 30 metres. The colour of the float may be blue, milky-white or greenish at the base. The ones that occur in Indian coastal waters are generally small, with a float 10 to 12 cm long, with usually a bluish to purplish-violet float (see SCIENCE TODAY, July 1973, p. 49). *Physalia* specimens are mostly washed ashore during the pre-monsoon period in the Bombay coastal waters. On the Madras coast, there is no fixed season nor are they very common.

S. N. KULKARNI

Eurythoe **(bristle worm). At right is shown a species found commonly on Indian shores. The colour photograph shows another variety**

Small jelly fishes (so called because of a gelatinous substance, mesogloea, in their body) are generally small, with a dome-, bell- or disc-shaped umbrella. The genera such as *Sarsia*, *Liriope* and *Olindias* have been reported to sting humans. The last two are universally distributed in

Pterois **(turkey fish or zebra fish or lion fish). Among the most beautiful coral-reef fishes, these are found in shallow coastal waters in the rocky shore or around the coral heads. They are commonly called turkey fish as they spread their coloured, fan-like pectoral fins and lace-like dorsal fins like a turkey displaying its plumes. Stings are extremely painful**

Octopus **(devil fish)**

Sepia **(cuttle fish)**

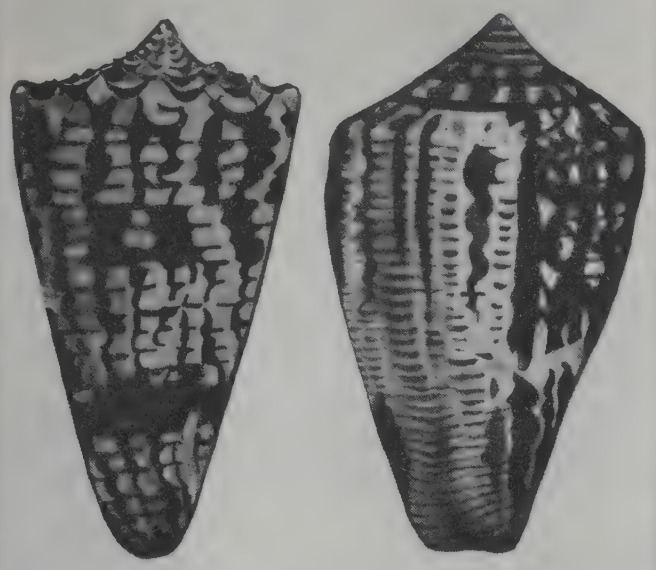
warmer parts of all the oceans. ue jelly fishes are, however, large, ne growing up to three metres oss the bell. The tentacles in some cies may be more than 36 metres g. In shape, they are cuboidal, me-shaped, flat, disc-shaped or wl-like, semitransparent and often h brilliantly coloured gonads, ten- les and radial canals (of the tro-vascular cavity). Found in llow coastal waters or in the open , a few species have been recorded en from depths of 3,600 metres more.

A number of jelly fishes have, so , been reported to sting humans. t the most venomous are the sea sps (Cubomedusae), a group of y fishes with four-sided cup-shaped brella and a more or less flat top. nera such as *Chiropsalmus*, *Chiro-*, *Carybdea* and *Chirodropus* are cluded in this group. They may w to about 10.cm height and 5 cm dth. These jelly fishes are distribut- throughout the warmer seas. They mmonly occur in quiet, shallow ters of bays, estuaries and in ters with sandy bottom. Other portant jelly fishes, as far as toxi- y is concerned and occurring in dian coastal waters, are *Cynea* a blubber), *Pelagia* (mave blubber), *ctylometra* (*Chrysaora*), *Lobonema* and *usithoe*. Another common venom- s jelly fish is *Aurelia* (moon jelly fish).

Only a few species of the marine nelids such as sea mouse or bristle rm (*Chloeia*, *Eurythoe* and *Hermodice*), lychaete worm (*Eunice* and *Lumbri- ereis*) and blood worm (*Glycera*) ve so far been reported as veno- ous. Annelids are worms made up ring-like segments (see p. 28). ey occur in sea water, fresh water d even on land. Marine annelids e included in the class *Polychaeta*, olus = many, Chaite = hairs), ving many hair-like bristles. They e distributed from the seashore to pths of 5,000 metres or more. enerally small in size, they grow to long as 5 to 10 cm. However, the istle worm *Eunice aphroditus* may ow to a metre or more in length. he venomous bristle worm *Eury- oe complanata* is common on Indian ores. The body of this animal is ongated and flattened, growing to out 140 mm, and is usually greyish- een in colour. They have well veloped, thick, hollow, poison-con- ining setae (hair-like structures) in e parapodia (side feet).

Molluscs constitute e largest group of biotoxic marine vertebrate animals. Molluscs are ft-bodied and unsegmented, usually

CONUS



(Left) *Conus zonatus*, **found in the Andamans. (Right)** *Conus mutabilis*, **found on the Bombay shores**

with a calcareous shell; the shell may be external, internal, vestigial or even absent. Venomous molluscs which can sting humans are the cone shells (*Conus*, class Gastropoda), and devil fish (*Octopus*), squid (*Loligo*) and cuttle fish (*Sepia*) belonging to the class Cephalopoda.

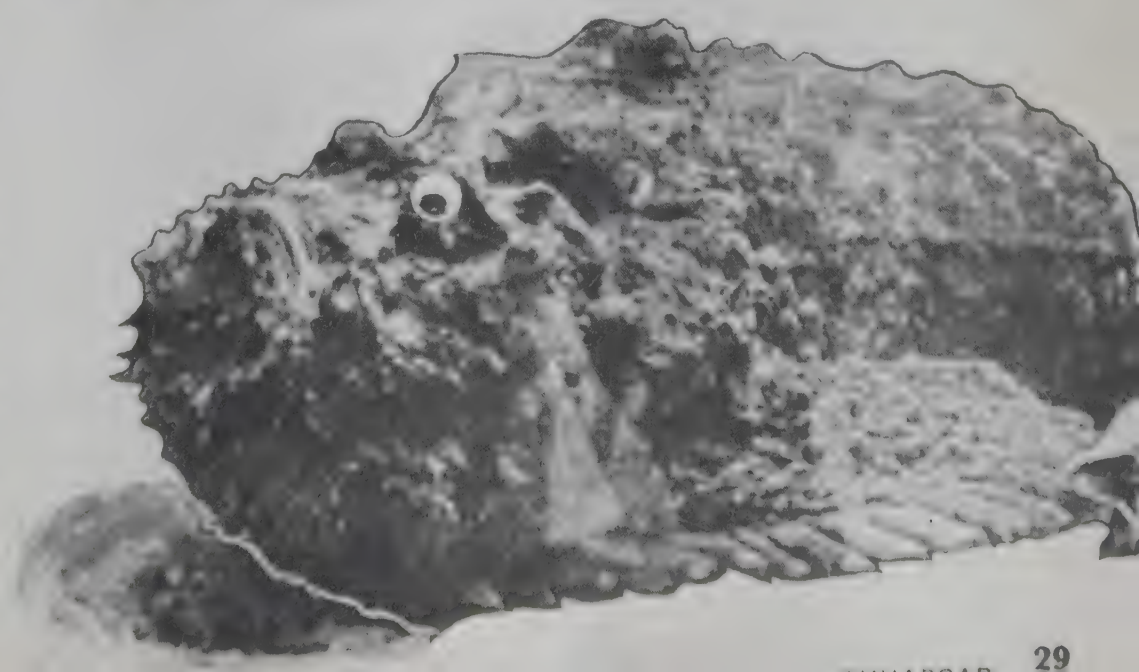
Cone shells can be distinguished from the other gastropod shells by a large body whorl of elongated conical shape with a long, narrow aperture. The surface of the shell is smooth and variously coloured with a lace-like pattern, or white with a dotted brown pattern. They are usually nocturnal, and live buried in the sand or under stones or corals during the day with only the tip of the siphon exposed. There are about 400 species of cone shells, confined mostly to the tropical and sub-tropical seas. They are most abundant in the shallow waters of the tropical region. All the members of this genus possess a venom apparatus, which is normally used to paralyse the prey (other molluscan animals, worms, etc) and, therefore, all species of *Conus* are potentially dangerous to man.

Cephalopods are marine molluscs with a crown of appendages (arms and tentacles) with suckers in the head region. The octopuses have eight arms. They are generally found in coastal waters up to depths of about 180 metres. Many of them are found in the rock pools in the intertidal zone. The cuttle fish and the squid have eight arms and two long tentacles. They prefer the open sea. The cephalopods are widely distributed in all tropical and temperate seas but the true octopus is mainly found in warmer waters. The cephalopods may grow to a large size. Bartsch (1917) had recorded an octopus nine metres long. Squids may grow to 18 metres or even more.

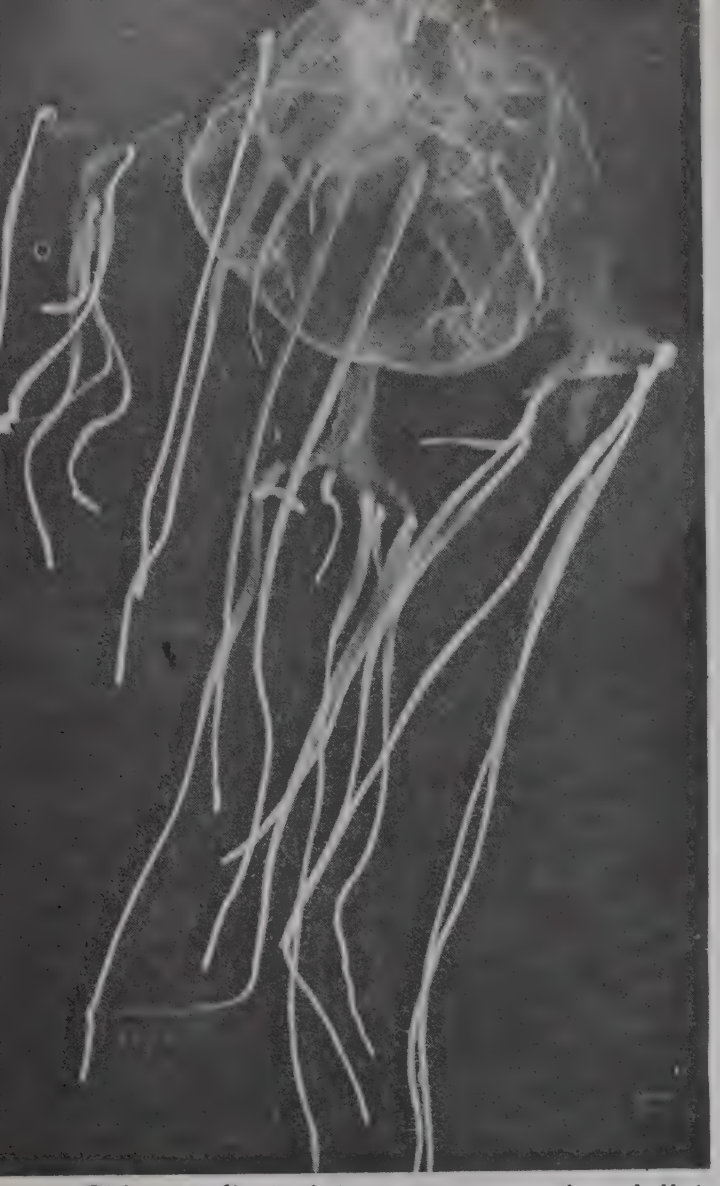
Echinoderms are pentamerous (five-sided) animals without a definite head. The body is star-shaped, or rounded or cylindrical, usually with arms (five or more) and spines covering the body. All echinoderms are marine, widely distributed in all the seas at all depths from the shore to the bottom of the sea. Starfishes, brittle stars and sea urchins are some of the echinoderms so far reported as venomous. The most venomous starfish is *Acanthaster planci*, a common species occurring in much of the tropical Indo-Pacific region. It grows to a large size, to 60 cm or more in diameter, and possesses 13 to 16 arms provided with long venomous spines. The only brittle star which has so far been reported as venomous is *Ophiomastix annulosa* occurring in the Indo-Pacific region. All the sea urchins are considered to be venomous since all of them are provided with small, poison-containing seizing organs, the pedicellariae (see box on p. 32) and spines. Sea urchins have a globular or flattened body enclosed in a hard shell or testa, and covered by spines.

Vertebrates

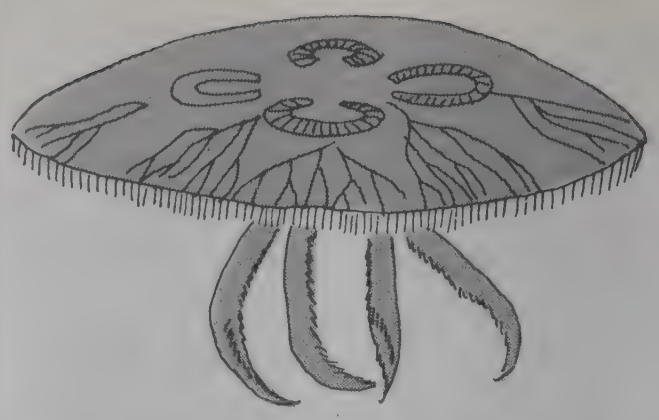
Over 200 species of fishes are known to be venomous. These fishes are mainly divided into two groups — cartilaginous (Elasmobranchii) and bony (Osteoichthyes) fishes. While the endoskeleton in the former is made up of cartilage, it is bony in the latter.



Synanceja **(stone fish). A type of scorpion fish commonly found in the tide pools. They remain motionless under rocks, or buried in sand or mud. Stings from this fish are sometimes very severe and the victim has been found to jump about wildly, scream and lose consciousness**



Chironex fleckeri **(sea wasp or box-jelly). It is one of the most dangerous venomous marine animals known so far. Death within 30 seconds of its sting has been reported. They are found in the seas of the Northern Territory and North Queensland, Australia**



Aurelia aurita **(moon jelly). It is a very common jelly fish in tropical and temperate seas. It grows up to 40 cm in diameter. It is usually colourless or with variable faint colours. Stings from this jelly fish are generally not very painful**

upper layers of the sand or mud. The body is flattened, forming almost a circular disc. The tail is mostly long, armed with a serrated spine which forms the sting.

Sharks that possess dorsal fin spines (see p. 33) are believed to be venomous; there are reported cases of the spiny dog fish (see p. 33) (*Squalus acanthias*) and the horn shark (*Heterodontus francisci*), injecting venom into humans. These sharks are, however, found mostly in the temperate waters. Chimaeras, known commonly as rat or elephant fish, are also confined to the temperate seas, mainly the north Atlantic and the North American Pacific coast.

Among the cartilaginous fishes reported as venomous are sting rays, some of the sharks and chimaeras. Sting rays are the most important group of venomous fishes because they are responsible for the highest number of serious or even fatal fish stings. Most of the sting rays are marine, inhabiting shallow coastal waters, bays, river-mouths, and brackish waters of tropical and temperate seas. They are bottom-dwellers and sluggish; most of the time, they remain hidden almost completely in the

Among the bony fishes, the widely distributed family Scorpaenidae (scorpion fish, stone fish, etc) is highly venomous. Their dorsal fins have about 12 to 13 poisonous spines; they occur in all tropical and temperate seas. Scorpion fishes are found in coastal waters, mainly on rocky shores, around coral heads, among underwater debris, or sea weeds, in the creeks, estuaries or even in the coastal rivers. Some of them may lie buried in the sand. Scorpion fishes are divided mainly into three groups, based on their venom organs *pterois* (zebra fish, turkey fish lion fish); *scorpaena* (scorpion f proper); and *synanceja* (stone fish)

All marine cat fishes have sha stout spines on the dorsal and pe toral fins (see p. 33) and can infl severe injury to the victim. Thou all of them are considered venomou the actual venom has so far be studied in only two species, *Plotos lineatus* (oriental cat fish) and *Gal chthys felis* (Mexican cat fish). T marine cat fish can be identified b its greatly developed lips, usual with long barbels.

A number of bottom-dwelling ven mous marine fishes remain partial or almost completely buried muddy or sandy coastal waters, bay estuaries or even tidal rivers of tropic and temperate regions; for instanc the weever fish (family: Trachinidae the toad fish (family: Batrachidae and the stargazers (family: Uranoscopidae). The dorsal and opercula spines (spines in the gill-cover) ar venomous in the first two groups fishes, whereas the shoulder spine form the venom apparatus in the stargazer

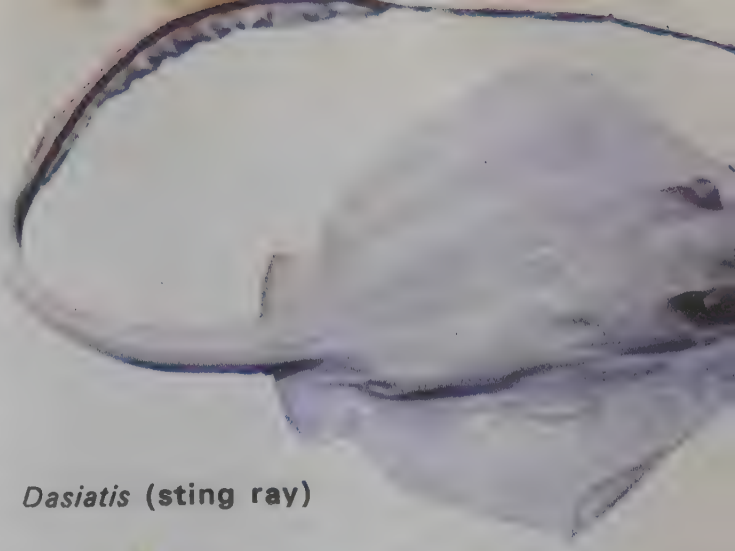
The surgeon fish (*Acanthurus*) an the closely related trigger fish (*Mona canthus* and *Balistes*) are gregariou venomous fishes. They abound in th seas in shoals, on the rocky shores o over coral heads. The rabbit fis (*Teuthis*), with sharp spines in th dorsal, ventral and anal fins (see p 33), is also considered venomous Other common fishes of our coasta waters which are supposed to b venomous are the butterfly fish (fami ly: Chaetodontidae) and scats (family Scatophagidae), but they have no been studied.

The highly venomous sea snake (see p. 35) are widely distributed

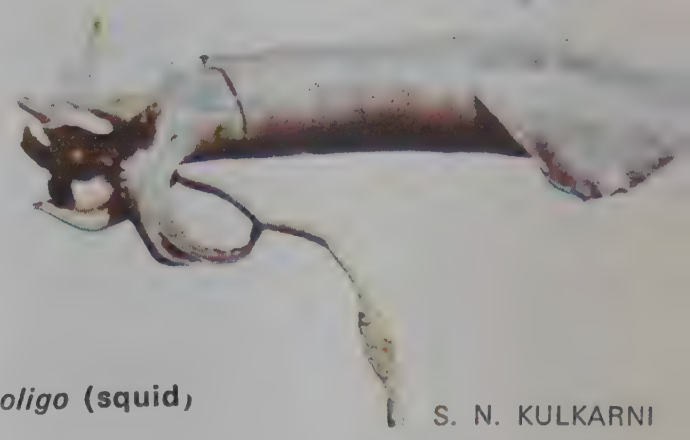
DISTRIBUTION OF VENOMOUS SEA CREATURES: 1. *Lytocarpus* **(***Pennaria,* **too, is found in this region) 2.** *Conus* **3. Eurythoe 4. Se anemone 5. Brittle star 6. Sea urchin 7. Starfish 8. Octopus 9. Chiropsalmus 10. Moon jelly fish 11. Toad fish 12. Sea snak 13. Butterfly fish 14. Scorpion fish 15. Rabbit fish 16. Cuttle fish 17. Squid 18. Surgeon fish 19. Trigger fish 20. Sting ray**

Physalia **(Portuguese-man-of-war or blue-bottle). This is actually a floating colony of small coelenterate animals. The individuals of the colony are attached to a float which is filled with a gas secreted by the gas gland of the float. The animal is carried from place to place by water currents or winds. Very often, they are carried ashore in large numbers where they die. The dead *Physalia* should not be touched, because the dried tentacles may retain the toxicity for two years or more**

S. N. KULKARNI



Dasiatis **(sting ray)**



Loligo **(squid)**

S. N. KULKARNI

roughout the tropical Indian and acific oceans. But there are no sea akes in the Atlantic ocean, the lediterranean sea and the Red sea; ey cannot tolerate low tempera- ures, generally below about 20°C. ea snakes have been spotted from oastal waters to 1,600 km or ore out in the sea. Though diffe- ent kinds of sea snakes occur along e Indian coasts, various species of *ydrophis* and *Pelamis platurus* are ore common.

tings and their effects

How do all these nimals inject the venom into the ictim? The stinging organs range rom the minute but complex nema- ocysts in coelenterates to the power- ul jaws in the octopus, stout spines in he fishes, and fangs in the sea snakes. Marine animals of the same group ave almost similar types of stinging rgans (see box on p. 32).

Since stings from marine animals re not reported in many cases, there s reason to believe that there is a reat disparity between the number f reported cases and the actual umber of cases. As far as published ecords go, more than 500 cases of coelenterates' stings have been reported from various parts of the world from 1836 to 1960; more than 45 of these were fatal. Curiously, about 114 cases of human injury from jelly fish (various types) stings and nine cases of *Physalia* sting were reported from Cairns in North Queensland, Australia, during a short period from 1956 to 1960. It is estimated that about 1,500 cases of sting ray attacks occur each year all over the world. Other cases reported are of *Conus* stings — about 28 cases, eight of them fatal.

It is surprising that only two reports of coelenterates' sting have been recorded in India. H. H. Scot (1921) reported several cases of *Physalia* sting, one fatal, and H. M. Evans (1945) reported another fatal jelly fish sting. Two incidents of jelly fish sting were reported to the author (personal communication). A boy of 11 to 12 years was stung by a jelly fish in Okha, Gujarat. He complained of severe itching and burning sensation which lasted three to four days. Two boys received jelly fish sting in Dabhol on the Ratnagiri coast in Maharashtra: one remained unconscious for two days before he recovered. It appears that cases of injury from venomous marine animals are not generally reported in India, and one of the reasons is the total lack of knowledge about the cause of injury or even death. Often, such deaths in the sea may be attributed to drowning or even heart failures.

Various researchers have worked on different aspects of the venoms in a number of marine animals. It is not possible to review, within the confines of this article, all the work, nor all the aspects. We shall, therefore, discuss the salient features of some important studies.

Coelenterates' venom has been variously described as thalassin, hypotoxin, congestin, meduso-congestin, etc. However, it has been established

(Left) *Ophiomastix annulosa* **(brittle star). The only brittle star which has so far been reported venomous. It grows to about 30 mm across the central disc. The arms which are five in number grow to about 250 mm in length. It is found in the Indo-Pacific region. (Right)** *Acanthaster planci* **(starfish). It is the most venomous star fish**

Two species of sea urchins

that the venom is protein in nature, and that the toxin activity is largely due to one of the peptides. The polysaccharide is either absent or very little, if present. It has also been found that the pain and release of histamine in the victim's body is caused by 5-hydroxytryptamine. Intravenous administration of different extracts from various coelenterates causes muscular paralysis, vomiting, respiratory distress, rolling on the ground, cardiac arrest and death in laboratory animals. Various other symptoms have also been recorded by different workers.

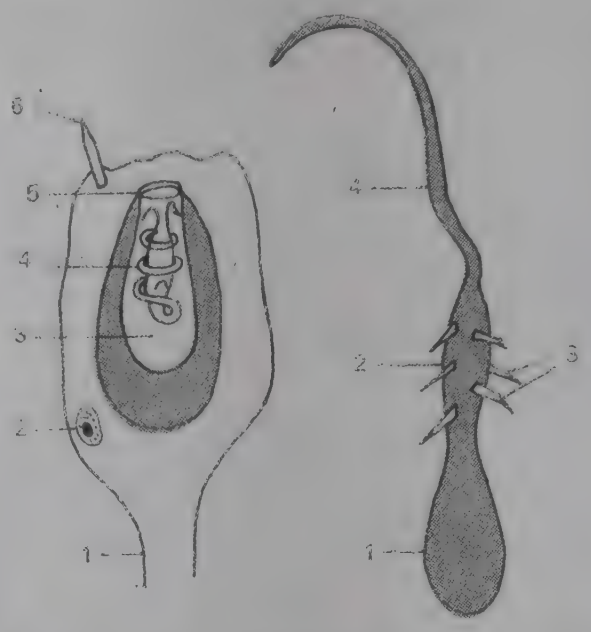
Stings from contact with tree-like branching hydroid colonies and small jelly fishes like *Liriope* may vary from a mild stinging sensation to severe itching, chill, fever, etc. *Physalia* sting may cause intense local pain, headache, faintness, collapse, chills and fever, vomiting, etc; death has also been reported. True jelly fish sting causes severe burning, throbbing or shooting pain, which may render the victim unconscious. The sea wasp (*Chironex fleckeri*), a jelly fish which occurs in northern Queensland and in the Northern Territory, can kill a person in less than a minute after contact with the tentacle. At least 50 deaths from sea wasp stings have been recorded off the east coast of Australia following cardiorespiratory failure. Contact with sea wasp tentacles can also result in acute local pain and inflammation, often with permanent scarring.

Though the chemical properties of *Conus* venoms have not yet been fully understood, it is believed that it consists of a complex of active substances, including protein, quaternary compounds and possibly amines. Extracts from different parts of the venom apparatus were found to be lethal when injected into animals such as mice, fish and other molluscs And, as mentioned earlier, human fatalities from *Conus* sting have been recorded. The pain from the *Conus* sting has been compared with a wasp sting. Numbness at the wound site and swelling of the affected part are some general symptoms. The numbness may spread to other parts, particularly about the lips and the mouth. In severe cases, total general muscular paralysis has been observed. Often, the vision blurs. Death occurs due to cardiac failure.

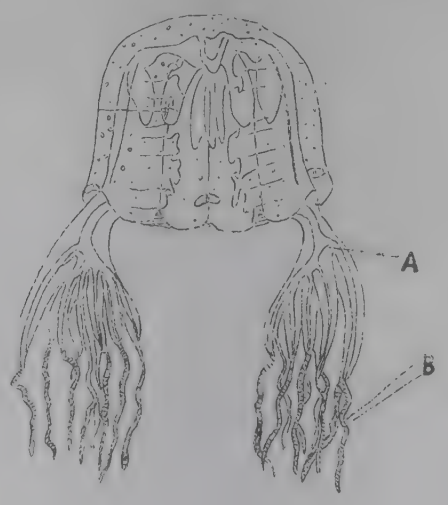
Certain toxic substances have been found in the salivary gland secretions of various species of *Octopus*. F. Ghiretti called the venom cephalotoxin. Its chemical composition is not yet known, but it is thought to be a glycoprotein (proteins with carbohydrates). The toxic factor has

THE VENOM APPARATUS

Peculiarly, the venom apparatus in the venomous marine animals of the same group has almost similar types of stinging organs. Thus, the venom apparatus in all coelenterates consists of nematocysts, located mainly in the tentacles. These are minute (about 5μ to 1·12 mm in length), capsule-like complex structures situated inside a cell (cnidoblast) or epithelium (see figure). The capsule is filled with a poisonous fluid and contains a hollow thread tube. The venom is carried from the capsule through the thread tube into the victim's tissues.



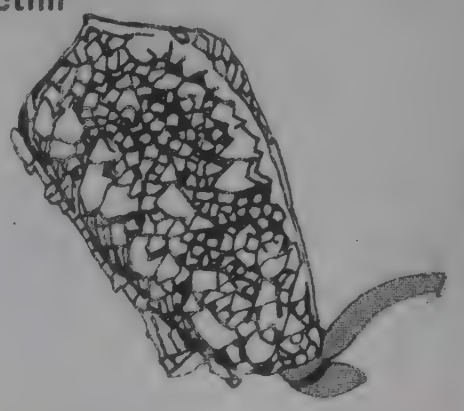
Structure of nematocyst: (Left: undischarged) 1. Stalk 2. Nucleus 3. Capsule filled with venom 4. Thread tube 5. Operculum 6. Cnidocil or the trigger. (Right: discharged) 1. Capsule 2. Butt 3. Spines of the butt 4. Thread tube. The thread tube which remains coiled in the capsule is lashed out by inverting itself, when the cnidocil or the trigger is stimulated. The venom is injected through the thread tube



Chiropsalmus **(sea wasp). A cubomedusa which grows to be about 100 mm high and 140 mm wide. Four wing-shaped or spatula-shaped pedalia with 7-9 fingers and tentacles are the peculiarity of this jelly fish. It has been recorded from Indian coastal waters. The sting may even kill a man (A: pedalium; B: tentacles)**

In marine annelids, it is the chitinous hair-like structures, the setae, projecting from the fleshy bilobed side-feet (parapodia), which form the main stinging organ. The setae appear

(Right) Two types of radular teeth in cone shells. Radula is actually a ribbon-shaped saw-like membranous structure containing many teeth arranged in definite rows. However, in *Conus*, the radular ribbon is absent and the entire radula remains in the radular sheath. The teeth are loosely arranged in two rows. Mostly, one tooth is used at a time. The tooth, filled with the venom received from the venom apparatus, remains at the end of the elongated proboscis with the lance-shaped tip pointed outward and is shot out into the victim

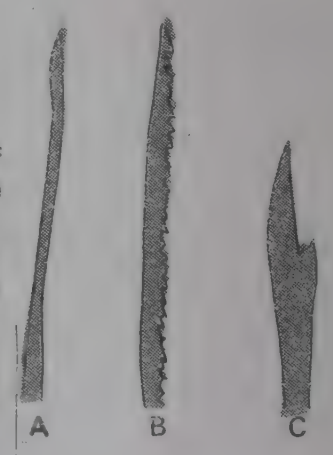


(Left) Co shell sti

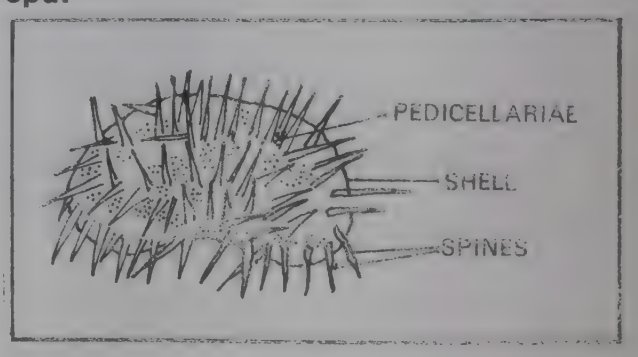
to be hollow, containing poison. In the blood worm (*Glycera*), the jaws act as the stinging organ. Each jaw is connected to a venom gland.

The venom apparatus in the cone shells (*Conus*) consists of a venom bulb, venom duct, radular sheath and radular teeth (see figure). However, recent studies by Alan J. Kohn of the USA and others have shown that the venom is probably produced by the glandular epithelium of the venom duct. The sting is inflicted by means of a single venomous radular tooth or up to six teeth.

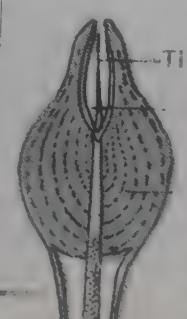
In the cephalopods (octopus, cuttle fish and squid), the salivary glands



Various types of setae of the bristle worm (*eurythoe*). A. smooth-pointed seta B. harpoon seta with serrations on the side C. stout forked seta D. slender seta with a small spur

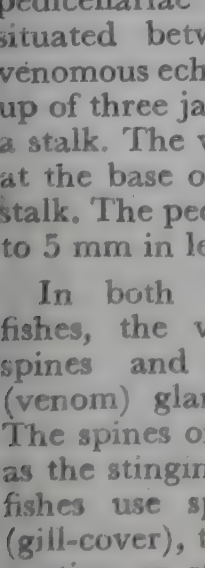


(Above) A sea urchin showing the spines and pedicellariae. (Right) Poison spine of a sea urchin



nd the jaws form the venom appa-tus. The animals have two pairs of livary glands and, in some cases, a blingual gland, which produce the xic substance. The animals first punc-ure the skin of the victim by two beak-haped jaws and then the venom is ntroduced.

The spines and pedicellariae are he stinging organs in the echinoderms starfish, brittle star and sea urchin). The spines are either solid or hollow. n the starfish, the poison is produced y the glandular cells of the epidermis outer layer of the skin), whereas in the ea urchin, it is produced by the

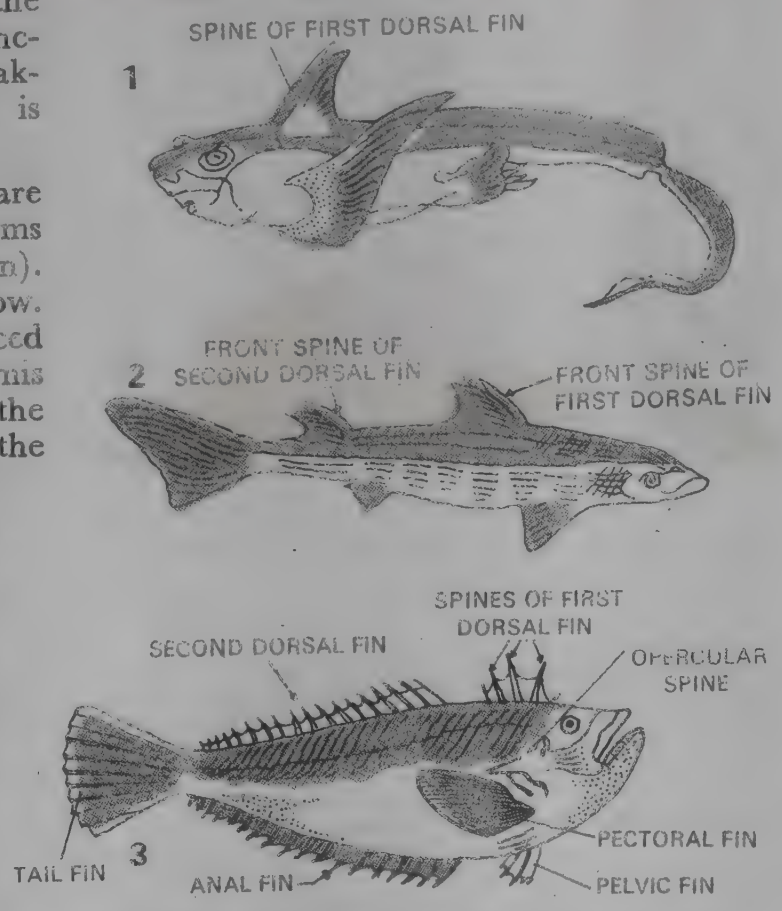


(Left) The pedicellariae of the sea urchin. 1. Stalk. 2. Axis of the stalk. 3. Venom gland. 4. Aperture of the gland. The venom gland has been observed only in the globiferous pedicellariae (below). The pedicellariae are found scattered among the spines of the outer shell or testa of the sea urchin

venom sac or poison bag enclosing the tip of the spine (see figure). The pedicellariae are small seizing organs situated between the spines in all venomous echinoderms. They are made up of three jaws or blades at the tip of a stalk. The venom glands are located at the base of the jaws or around the stalk. The pedicellariae may be 1.5 mm to 5 mm in length.

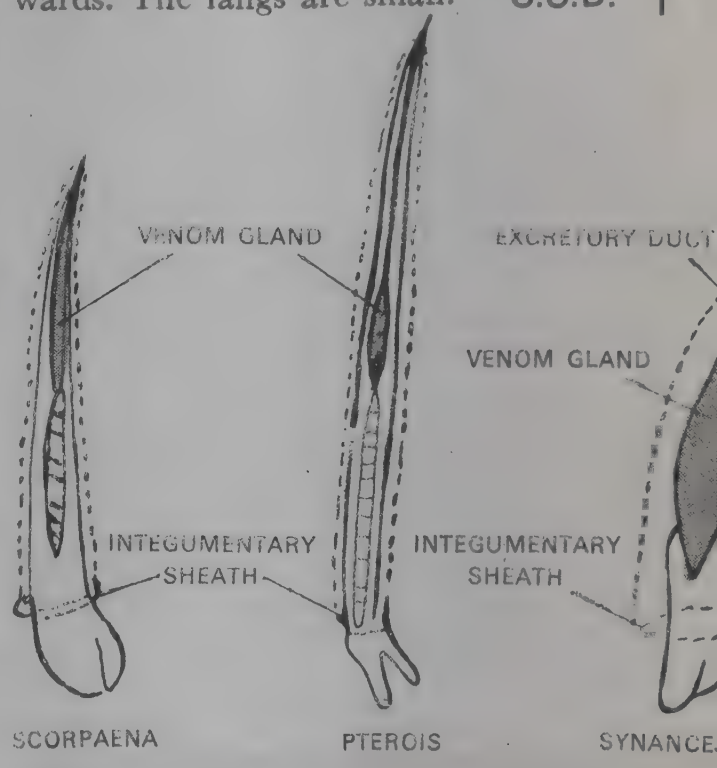
In both cartilaginous and bony fishes, the venom apparatus is the spines and the associated poison (venom) glands or glandular tissues. The spines of the fins are mostly used as the stinging organ. However, many fishes use spines of the operculum (gill-cover), tail, caudal peduncle (free portion or stalk of the tail) and the shoulder region as the stinging organ. The venom gland or the glandular tissues which secrete the toxic substance are made up of glandular epithelial cells. They are located

(Below) Spines and fins used for stinging in fishes: 1. *Chimaera* (rat fish or elephant fish), 2. spiny dog fish (*Squalus acanthias*), 3. weever fish (*Trachinus*)



either within the grooves of the spines, or around, or at the base of the spines. The poisonous substances are either introduced directly into the tissue of the victims by the spines, or the wounds are first inflicted by the spines and then the venoms are injected into the wounds.

Fangs and poison glands are the venom apparatus in sea snakes. The fangs, like all other poisonous land snakes, are situated on the upper jaw but they lie slightly or far backwards. The fangs are small. S.S.B.



Different types of venom apparatus (dorsal stings) of the three types of scorpion fish. The venom glands can be located in the paired grooves of the spine after removing the integumentary sheath

STINGING ORGANS OF VENOMOUS FISHES AND THEIR EFFECTS

SPECIES	STINGING ORGAN	EFFECTS OF STING ON MAN (CLINICAL)
Horn shark (*Heterodontus francisci*)	Front spine of both the dorsal fins	Immediate stabbing pain, swelling and redness of the affected part. Death (reported)
Spiny dog fish (*Squalus acanthias*)	Front spine of both the dorsal fins	Local swelling, increase in respiratory rate
Sting ray (*Dasiatis*)	Dorsal tail spine in the middle or one-third of the distance from the proximal end of the tail	Severe pain develops within 10 minutes; loss of speech after a few minutes. Death (reported)
Rat fish (*Chimaera*)	Front spine of the first dorsal fin	Serious wound
Scorpion fish (*Pterois, Scorpaena, Synanceja*)	12–13 dorsal fin spines, 2–3 anal fin spines, 2 pelvic fin spines	Immediate, severe and sharp throbbing or shooting pain which radiates from the affected area. Vomiting, convulsions, redness of the area about the wound, paralysis of the limb. Fever, respiratory distress, delirium. Death due to cardiac failure (reported)
Cat fish (*Plotosus lineatus, Goleichthys felis*)	4–5 dorsal fin spines, 10–11 pectoral fin spines	Immediate throbbing sensation which may radiate, severe pain, swelling and redness of the affected area, numbness and gangrene around the wound. Death (reported)
Weever fish (*Trachinus*)	4–7 dorsal fin spines, 1–2 opercular spines	Immediate burning, stabbing sensation, severe pain, faintness. Gangrene may develop
Toad fish (*Batrachus*)	2 dorsal fin spines, 2 opercular spines	Immediate severe pain radiating from the place of injury, swelling, redness and heat around the area
Stingrays (*Urolophus, Taeniura*)	2 [illegible] spines	Death (reported)
Rabbit fish (*Teuthis*)	13 dorsal fin spines, 1 pectoral fin spine, 1 pelvic fin spine	Painful stab (reported)

(Left) A nemertine worm with extended proboscis

been called eledoisin by V. Erspamer, and the sequence of the amino acids has also been determined. In laboratory experiments, it produced a state of general excitement followed by paralysis in crabs. The venom also affected the respiratory and other medullary centres in laboratory animals. In general, cephalopod (*Octopus*, *Sepia*, *Loligo*) sting produces an immediate pain with a sharp stinging or burning sensation in human victims. Other symptoms are swelling and redness about the wound, numbness of the mouth and tongue, difficulty in speech and swallowing and blurring of vision. Death within two hours after being bitten by an octopus has been reported. The small octopuses occurring in Indian coastal waters, particularly around the Madras coast, are reported to be very active and venomous.

S. N. KULKARNI

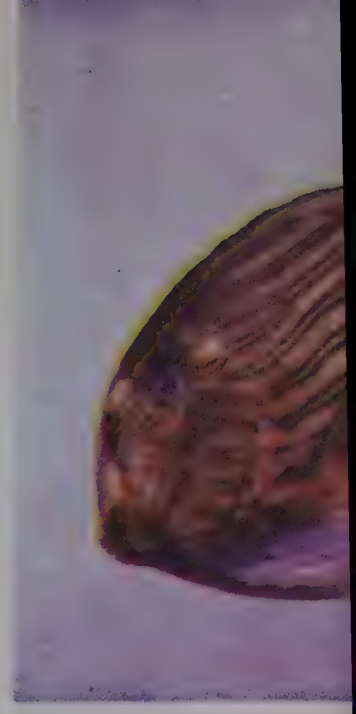
Siganus (*Teuthis*) **(rabbit fish)**

Among marine annelids, the poison of the polychaete worm, *Lumbriconereis heteropoda*, has been analysed. The toxic substance has been called nereistoxin ($C_5H_9NS_2$), and it is reported to affect the nervous system and the heart.

Sea urchin venom is more toxic. It causes paralysis and death in animals like rabbits and crabs. On the other hand, starfish venom, known as saponin, possesses strong haemolytic properties.

S. N. KULKARNI

Batrachus grunniens **(toad fish). These fishes are common in the Indian seas and also along the coasts of Sri Lanka, Burma and Malaysia**



B. F. CHHAPGAR

In human beings, stings from the annelid worm and echinoderms (starfish, brittle star and sea urchin) may cause immediate inflammation of the skin, redness, numbness, itching or even paralysis of the limbs. Generalised paralysis, respiratory distress of even death may occur from sea urchin sting.

Some chemical and toxicological similarities have been observed in the venoms of different groups of marine fishes. For instance, sting ray venoms are believed to be a protein of average molecular weight (over 100,000); a number of amino acids has also been identified. The venom has been considered a strong neurotoxin. Scorpion fish venom is believed to be a high molecular protein; venom of one of the family, the stone fish, *Synanceja horrida*, is said to be both haemotoxic and neurotoxic — the venom produces haemolysis in animals such as sheep and guinea-pig. Cat fish (*Plotosus*) venom is also believed to have both haemotoxic and neurotoxic properties. Intravenous, subcutaneous and intraperitoneal injections of the venom resulted in muscular spasm, respiratory distress and death in laboratory animals. Weever fish (*Trachinus*) venom caused respiratory paralysis and death in frogs and rabbits; the venom has also been reported to be haemolytic. Extracts of the venom-producing tissues of the weever fish have been found to contain 21·7 per cent protein, besides nitrogen, other soluble lipids and carbohydrates.

Uranoscopus **(stargazer). Various species of stargazers occur in Japan, Korea, China, Philippines, eastern Atlantic region and Mediterranean sea. Sting from European stargazers can be fatal**

Chaetodon **(butterfly fish)**

B. F. CHHAPGAR

Balistes **(trigger fish)**

anthurus **(surgeon fish)**

Generally, stings of various marine hes produce immediate and in- nse stinging, stabbing, throbbing shooting pain in human beings, companied usually by swelling and

ydrophis **(sea snake)**

edness about the injured parts. How- ver, the symptoms vary in intensity nd quality, according to the species. tings from scorpion fish, weever fish, at fish and sting rays are extremely ainful, and may even be fatal.

Sea snake venoms are more toxic han land snake venoms. All the eurotoxic components of sea snake enoms are basic proteins of low olecular weight. The amino acid equence of the neurotoxin of sea nakes is closely related to that of obra neurotoxin and cardiotoxin. The mode of action of the toxin has lso been found to be similar to that f cobra venom (see p. 46).

Sea snake venom is extremely langerous (curiously, fresh water nakes are not venomous). The com- mon symptoms of sea snake bite are muscle-ache, pain and stiffness of movement in the tongue, throat, neck and limbs followed by a dry feeling in the throat, general weakness, vomiting, difficulty in swallowing and speaking, and respiratory failure. Breathing becomes shallow and death occurs within 24 hours of the bite. The most rapid death recorded so far was within 2½ hours of the bite and the longest, 24 days. The latent period from the bite to the time the symptoms begin to show varies from half an hour to 3½ hours. Sea snake bites are mostly without any pain or swelling at the wound site. One, two or more small circular fang marks may be noticed. In some cases, however, serious poisoning may occur without clear fang marks.

TREATMENT OF STINGS AND PRECAUTIONS

Treatment of stings of most of the marine animals should be directed towards: (*i*) relieving pain; (*ii*) combating the toxic effect of the venom; (*iii*) controlling primary shock; and (*iv*) preventing secondary infection.

In the case of coelenterates, annelid worms and echinoderms stings, the tentacles, setae, spines or pedicellariae sticking to the skin of the victim should be immediately removed by rubbing with a bathing towel, sand or any available material. Alcohol, oil or any other material available should be applied to the injured part to stop the activity of the stinging organ.

In the case of a puncture wound by fish spines, a small incision should be made across the wound (because the size of the wound is very small), and the wound should be sucked to draw out the venom. A ligature may also be tied at once near the wound to prevent the venom from spreading further. Soaking the injured part in hot water for about an hour has been suggested by many workers. This may destroy the venom. But the water should be maintained at as high a temperature as can be tolerated by the victim. Hot, moist compresses should be used if the injury is on the face or the body.

The lacerated wounds inflicted by tiny barbs of sting ray or cat fish spines should be immediately washed with cold salt water or sterile saline to prevent infection. Cephalopod (octopus, cuttle fish and squid) victims should be treated in the same manner as venomous fish stings.

Sea snake bites should be treated like any other poisonous snake bites (sea p. 46). A firm ligature should be tied and antivenom should be given. However, incision and suction have been found to be ineffective in the case of sea snake bites.

There are no known antidotes yet for most of these bites and stings; an antivenom has been recently developed for scorpion fish bite.

Though it may not be easily possible to detect the presence of any marine venomous animals in a place, one could, however, take certain precautions. For instance, shuffling the water a little above the bottom or prodding the bottom with a stick may scare away organisms such as sting rays buried in the sand.

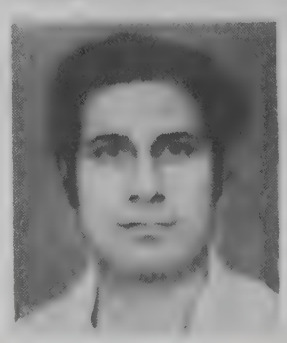
Do not go close to a *Physalia* or a jelly fish, because the tentacles may be spread over a long distance, sometimes even up to 36 metres. And do not touch even dead jelly fish or *Physalia* washed ashore, because the venom remains active for a considerably long time. Do not also touch any shell which is cone-like, particularly near its aperture through which the proboscis is projected. Handle the shell, if it all, at the elevated portion. Animals like the scorpion fish should not be picked up placing one's hand directly on them. Similarly, avoid contact with dorsal fins of all venomous fishes, as most of them are used as stinging organs. The pelvic and anal fins (see box on p. 32) of scorpion fish, the pectoral fins of cat fish and opercular spines of weever fish and toad fish also should not be touched. Echinoderms such as starfish and sea urchin, which are common in sandy or rocky shores, should not be handled directly.

Fish like the sting ray and cat fish are eaten after removing the stings and the fins. The squid and the cuttle fish are also eaten. Boiling destroys the toxic factors in the venom.

S.S.B.

Jelly fish sting marks on the leg

J. H. BARNES



Dr. Bhattacharya (36) teaches zoology at Siddharth College of Arts and Science, Bombay. He has carried out research on live marine zooplankton in the laboratory. He has also studied the venomous marine invertebrates on the Bombay coast.

SUSHMA

...and some that make deadly dishes!

B. F. CHHAPGAR

These ye shall eat of all that are in the waters:

All that have fins and scales shall ye eat:

And whatsoever hath not fins and scales ye may not eat:

It is unclean unto you.

Deuteronomy 14: 9-10

Since time immemorial, man has been eating *some* that are in the waters, if not all that "have fins and scales". It is difficult to establish if the Mosaic taboo given in the Bible and quoted above is scientifically valid, though ever since man started eating fish out of the sea he must have known about the dangers associated with some species of sea dwellers. However, the taboos are more often founded on tradition, and both the chemistry and the biogenesis of poisons in fishes are yet very much an uncharted field. Now that food planners are talking of turning more and more to the sea for meeting the protein needs of an exploding human population, the lacuna in our knowledge about fishes can indeed pose serious problems. But, then, how much do we really know about poisonous fishes?

Apart from food poisoning caused in the process of decay, where a dead fish may become contaminated by harmful bacteria, many living fishes are poisonous due to toxic substances present in their body during life. The term "poisonous" is used here in the restricted sense, and pertains only to the fishes having a harmful effect when eaten. This excludes the venomous, or acanthotoxic, fishes (discussed in the preceding article) in which the poison takes effect in the blood circulatory system, on injection. Fish poisons may be classified into the following groups:

a. *Sarcotoxins*, where the flesh (including the viscera and skin) contains the poison;

b. *Oötoxins*, where the poison is restricted to the reproductive organs of the fish;

c. *Haemotoxins*, that is, the poison is in the fishes' blood;

d. *Allyeinotoxins*, where the poison is mainly confined to the brain; and

e. *Hepatotoxins*, where the liver contains the poison.

By far the most notorious poisonous fishes are the puffer fishes. Known even to the Egyptians as early as 2700 BC, who called them *shepet*, their toxin is among the most virulent nerve poisons known to mankind. The puffer fish can be easily distinguished on account of its globular body. When confronted by an enemy, it gulps a large quantity of water which is retained in the sac-like ventral diverticulum of the stomach. The bloated body can remain distended for quite some time. When thrown ashore, it gulps in air instead of water, accompanied by a noisy grinding of the teeth. Strollers on Indian beaches can frequently spot them puffed up, especially during the monsoon.

Tetrodotoxin, the poison of the puffer fish (*Tetrodon* spp.), also occurs in its relatives, the porcupine or spiny puffer fish (*Diodon*), the sunfishes (*Mola* and *Ranzania*), and the sharp-nosed puffers (*Canthigaster*). True to the biblical warning, none of these fishes, belonging to the Order Plectognathi, have scales.

The skin, liver, ovaries and intestines are the most poisonous parts of the puffer fish. The flesh is usually safe to eat but may, at times, be toxic. Maximum concentration of the poison occurs when the reproductive organs mature. As little as one gram of ripe ovary, when eaten, may be fatal to human beings. The average mortality rate is 60 per cent of those affected. Tolerance or immunity cannot be built up by eating small (sub-lethal) quantities. There is no anti-serum or vaccine, as the poison is not antigenic.

Symptoms of poisoning may appear in the victim as early as ten minutes after eating, though sometimes they are delayed up to four hours. At first there is a tingling sensation in the lips and tongue, fingers and toes, developing into numbness of the extremities and then of the whole body. This is accompanied by lowered body temperature, profuse sweating and salivation, low blood pressure, headache, extreme weakness, nausea and anxiety. Vomiting, severe stomachache and diarrhoea follow. After some time, there is respiratory distress, manifested by shallow and rapid breathing, and the lips and body extremities turn blue (a condition known as cyanosis). As the nervous system gets affected, muscular twitching, trembling, slurring of speech and inco-ordination take place, paralysis sets in and, although the patient retains consciousness, death finally results from respiratory paralysis, within 6 to 24 hours.

There is no antidote for the poison. The poison should be removed from the body system by giving emetics or copious amounts of soda bicarb in water. Artificial respiration is an important therapeutic measure, together with administration of an analeptic such as pentylenetrazol. There are good chances of the patient recovering if he lives for 24 hours.

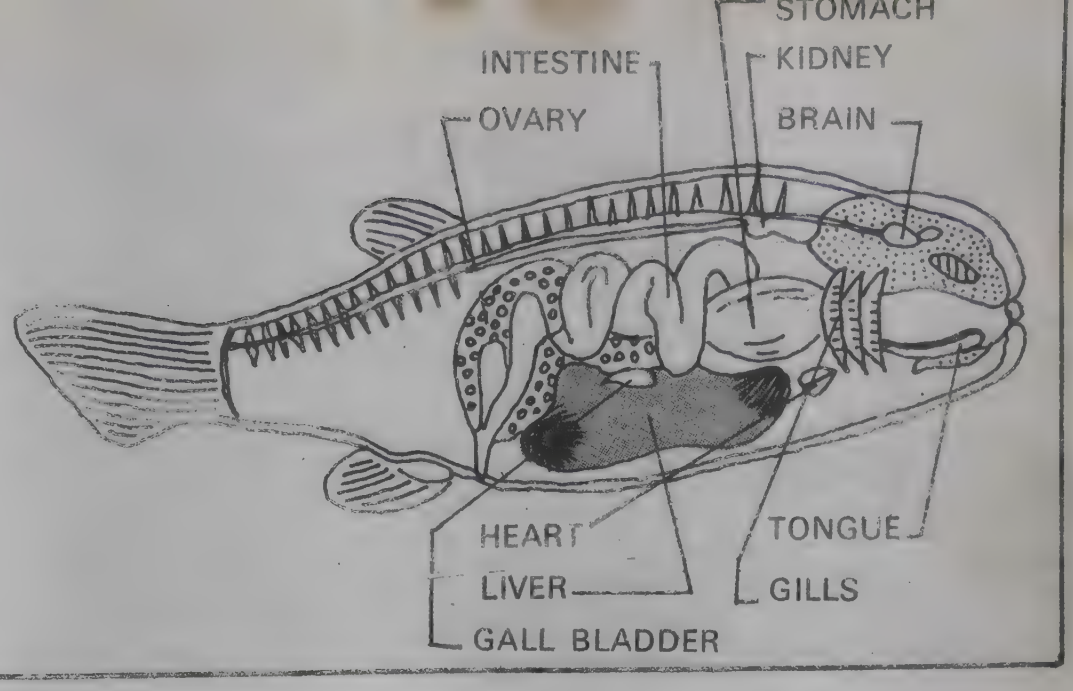
Throughout the world, the puffer fish is discarded as trash fish. Human casualties occur only when it is consumed unknowingly. [Dr. S. Jones, in his paper "Some deaths due to fish poisoning (ichthyosarcotoxism) in India", *Indian Journal of Medical Research*, *44*, 2, pp. 353–360, 1956, has dealt with puffer poisoning.] Surprisingly though, the Japanese consider it an epicure's delicacy, with the result that its sale fetches a high price. Not that the Japanese are unaware of the dangers. In fact, there is strict legis-

tive control, ranging from outright an on sale to an insistence on in-rming the customer that he is urchasing *fugu* (the Japanese name r puffer fish) and advising him of s toxicity. In restaurants, only censed *fugu* cooks are allowed to repare the dishes. Before being ranted a licence, these cooks have o undergo an intensive training, and ass an examination. Considering hat cases of *fugu* poisoning are rare n these restaurants (unfortunately, hough, common among Japanese who cook *fugu* at home), these cooks re highly respected. The ultimate in erfection is their ability to prepare ickled puffer roe (chiefly because, f all the organs, the ovaries contain he most potent poison). Perhaps, he trick lies in making the poison ose its potency over time — by a rocess of salting, mixing with rice ran and storing for three to four ears. About 40 per cent of the oxicity is said to disappear after even months' storage, and 70 per ent by 17 months. Cooking by rying, stewing, baking or boiling he fresh fish, on the contrary, does not inactivate the poison. Even the standard processing methods, such as boiling for ten minutes and then boiling under pressure to 116°C, for canning do not render it safe for consumption. Only cooking in a strong baking soda solution can inactivate the toxin, but then the flavour of the fish is destroyed and it is hardly worth eating.

In spite of the stringent regulations in Japan, over 2,700 persons have died there of puffer poisoning during 1900—1950. Why then do people go for this dangerous fish? Perhaps, the lure lies in the state of exhilaration (comparable to drinking alcoholic liqueurs) giving rise to a sensation of warmth, flushing of the skin, tingling of the tongue and lips, and euphoria, caused by the mild effect of the small amount of poison still remaining after preparation. Possibly,

Porcupine fish (*Diodon maculifer*), by inflating its body, presents a frightening array of spines to its enemy

Body parts of a puffer fish



the best explanation was provided by the Japanese sage Hosetsu Namba, in 1880: "Although there are many occupations in the world, some people engage in stealing instead of entering one of them. Although there are many women in the world, there are some men who become adulterers instead of marrying the women. Although there are many kinds of foods in the world, some people like to eat poisonous fugu instead. These three groups of people make up an extremely stupid trio."

By an extremely rare coincidence, the eggs and embryos of the California newt, *Taricha torosa*, contain the same tetrodotoxin as is found in puffer fishes. First isolated in pure form in 1963, the poison was named "tarichatoxin", but was subsequently found to be chemically identical with tetrodotoxin. Why two such widely different animals should develop the same toxin remains one of the mysteries of nature.

Tetrodotoxin is a poison found only in the roe (unshed eggs) of fishes, though the other organs are edible. It occurs in a wide variety of fishes ranging from sturgeon (famed for its caviar), gar, trout and pike to minnows, catfishes and perches. It is also found in the following Indian fishes: three species of *Schizothorax* — freshwater fishes found in Kashmir and Assam, the marine catfish *Plotosus anguillaris*, and the marine sculpin (*Scorpaenichthys*). It also occurs in the common carp (*Cyprinus carpio*), a native of China but now found all over Europe and USA; it has also been introduced into India.

The poison is a lipoprotein and its concentration increases with the maturation of the reproductive organs. The symptoms of poisoning are bitter taste, headache, vomiting, diarrhoea, cold sweat, fever, a feeling of constriction round the chest, sometimes leading to coma and death, but usually recovery takes place in three to five days. Cooking is said to destroy the poison.

The blood of some Indian fishes belonging to the Order Apodes, such as eels (*Anguilla bicolor* and *Anguilla bengalensis*), morays (*Muraena, Gymnothorax* spp.) and snake eel (*Pisodonophis boro*), contains a haemotoxin which can affect man. Eels (*Anguilla*) are catadromous migrants, that is, the adults go from rivers to the sea to breed, but the young return to the rivers. Snake eels and morays are marine.

Drinking fresh (uncooked) blood of any of these fishes gives rise to

Mechanism of action of tetrodotoxin

Puffer fish poison has a specific effect on the migration of sodium, but not potassium, ions across a cell membrane.

Nerve fibres are surrounded by a membrane, the inside of which is electrically negative, the outside being positive, the voltage difference across the membrane being approximately 70 mV. Inside the cell membrane there is a high concentration of potassium ions, but little sodium or chloride. In the resting stage, the membrane is permeable to potassium and chloride ions but not to sodium. On stimulation, there is a sudden increase of permeability to sodium ions, followed by a slower, increased permeability to potassium. On cessation of stimulation, an active transport of sodium outward through the membrane restores the original ionic composition.

While local anaesthetics, such as procaine, block the action potential by preventing the movement of both sodium as well as potassium ions across the membrane, tetrodotoxin has a more selective effect in that it blocks the increase of permeability of the membrane only to sodium ions, the movement of potassium ions remaining unaffected.

B.F.C.

B. F. CHHAPGAR

The estuarine puffer fish (*Chelonodon fluviatilis*) (left) is one of the many species of poisonous puffer fishes. All puffer fishes, when harassed, can swallow water or air and inflate themselves (right) to prevent being swallowed by predators

B. F. CHHAPGAR

(Left) Chequerboard wrasse (*Halichoeres centriquadrus*)

Indian fishes : rabbitfish (*Siganus oramin*), surgeon fish (*Acanthurus triostegus*), sergeant major (*Abudefduf septemfasciatus*), goatfish (*Upeneus* spp.), and grouper (*Epinephalus* spp.).

Although itching, burning sensation in the throat and muscular weakness are present, the toxin predominantly affects the nervous system,

The sculpin or scorpion fish (*Scorpaena rosea*) is triply dangerous as it prod Ootoxin, transvects ciguatoxin and is venomous

nausea, vomiting, frothing at the mouth, diarrhoea with bloody stools and skin eruptions. More severe cases develop irregular pulse, respiratory distress, paralysis, and sometimes, death. A drop of blood placed on the tongue will produce a burning sensation, profuse salivation and redness of the lining of the mouth. A drop of blood accidentally falling into the eye will also cause a severe burning sensation, profuse watering and swelling of the eyelids, and redness of the conjunctiva. A feeling of a foreign body sticking in the eye will persist for several days. Repeated subcutaneous injections develop an immunity against the blood. Cooking destroys the poison.

Hallucinogenic fish poisoning sometimes called ichthyosarcephialtilepsis, is caused by the poison allyeinotoxin. This is concentrated in the head (brain) of the following

Painted morays (*Muraena tessellata*) are typical of the finless, scaleless fishes forbidden by Mosaic taboo

Cowfish (*Ostracion cornutus*), a poisonous relative of the puffer fish, is encased in a hard protective bony armour. The colony of hydroids it is feeding on convey toxin to the fish

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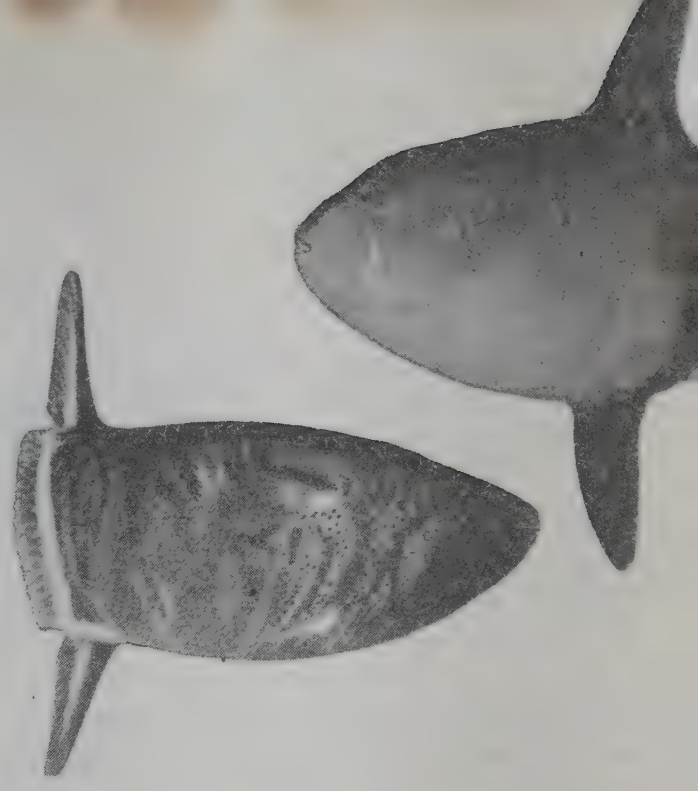
Marbled grouper (*Promicrops lanceolatus*) grows to over 230 cm and 200 kg in weight. Eating large specimens should be avoided as these are liable to be ciguatoxic



(Right) The ocean sunfishes *Mola mola* (top) and *Ranzania laevis* (bottom) are deadly, but are not normally consumed because of their unpalatable, watery flesh

giving rise to delirium, dizziness, loss of balance, and hallucinations. The patient has a sensation of severe constriction around the chest (like someone sitting on the chest). He also has frightening nightmares and a feeling of impending death. There are, however, no fatalities.

Very little is known regarding hepatotoxins in fishes. Symptoms, appearing within half to one hour, consist of the usual nausea, vomiting and fever. A severe headache, which is aggravated by the slightest movement of the head or eyes, is present. Peel-away of skin starts in three to six days and continues for up to a month. The liver may become enlarged. There are no fatalities.

THE CHEMISTRY OF SOME FISH POISONS

Tetrodotoxin is perhaps one of the few fish poisons which have been isolated in pure form. Its molecular weight is 329, the molecular formula is $C_{11}H_{17}N_3O_8$

It is an aminoperhydroquinazoline compound, and is peculiar in that a cyclic hemilactal structure does not occur in any other natural or synthetic compound. The poison, in solution, exists as a zwitterion with a hemilactal anion and a guanidinium cation. Thus, even comparatively minor alterations in its chemical structure destroy its pharmacological activity. Although the crude poison readily dissolves in water, the purified toxin is practically insoluble in water or organic solvents, but soluble in weak acid. It is inactivated when heated in acids below pH 4 or alkalis above pH 9. In neutral pH(7), it resists boiling for as long as one hour.

In the case of scombrotoxin, the amino acid histidine in the fish muscle is decarboxylated to histamine, which is a β-iminazolylethylamine having the molecular formula $C_5H_9N_3$; another decay product is saurine which can be separated from histamine by paper chromatography. Saurine is insoluble in ether, acetone, benzene and chloroform, but can be easily extracted with methanol.

Murexine, a poison contained in the hypobranchial, or purple, gland of *Murex* snails of the Mediterranean Sea, is more of academic interest, as it has been synthesised artificially. Also called urocanylcholine, it has the chemical formula $C_{11}H_{18}O_3N_3$.

B.F.C.

The poisoning is believed to be due to hypervitaminosis A (excessive vitamin A intake); hence the livers of sharks and rays, which are extremely rich in this vitamin, should be scrupulously avoided.

Ciguatera poisoning has the dubious reputation of having the largest number of transvectors of any marine poison — and an equally large amount of confusion! For, the biogenesis of the poison has not been elucidated, nor the actual mechanisms of transvectoring (imbibed from another species and passed on) the toxin(s) have been fully determined, and the chemical and pharmacological characteristics are poorly defined.

Ciguatera poisoning is caused by consumption of marine fishes which are normally non-poisonous and, therefore, edible, but which, in some places or at certain times suddenly become poisonous. It is unknown with freshwater fishes. Most, but not all, of the fishes which cause this poisoning — and there are over 300 species — are insular and benthic (bottom dwellers). However, usually only about 20 kinds are involved, mainly, snappers, groupers, jacks, barracudas, sharks, surgeon fishes and eels. The most toxic organ is the liver, followed by the gut and the gonads.

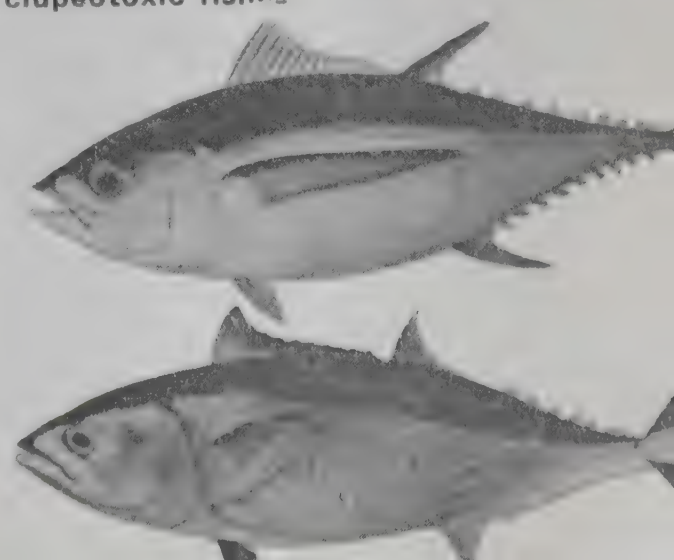
The symptoms of poisoning are a sudden onset of stomach ache, dryness of mouth, metallic taste, nausea, vomiting, abdominal cramps and liquid motions. There is also bodyache, a feeling of exhaustion and extreme weakness; the patient is unable to walk. The teeth feel loose and painful in their sockets. In severe cases, there may be a loss of hair and nails. There is also a peculiar reversal of the feeling of heat and cold, as exemplified in the classic case, quoted by Mann, of a naval officer who, a month after recovering from ciguatera poisoning, was seen subconsciously blowing on his ice-cream to cool it, as to him, it felt hot as if burning his tongue!

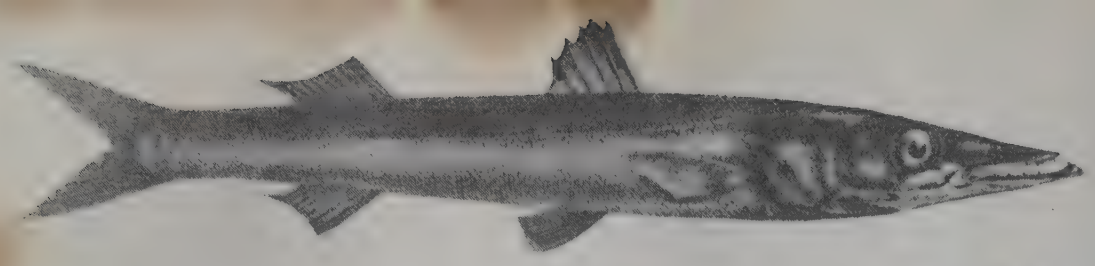
The mortality rate is 12 per cent and death may ensue as early as within ten minutes; but usually, it occurs after several days. Recovery in rare cases is slow, with excessive weight loss and extreme fatigue lasting for several years. Even after a lapse of 25 years, victims may suffer, during bouts of stress, from joint aches almost as acute as those during the original attack.

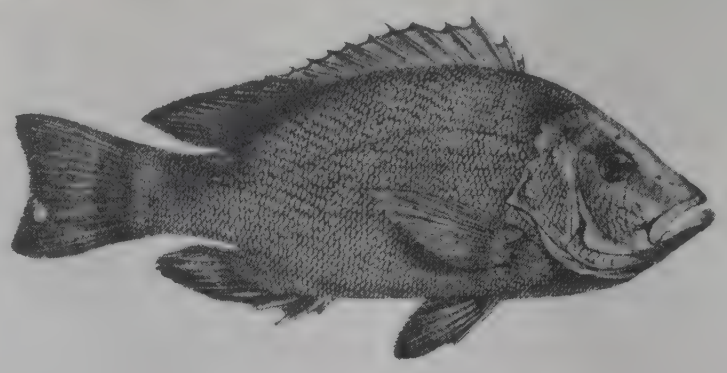
Scombrotoxin is different from the other fish toxins discussed earlier in that it is a product of bacterial decomposition of improperly preserved dark-meat fishes

Spoilt dark-meat fish flesh can be easily made out by its sharp peppery taste. Within a few minutes after eating, there is dizziness, intense headache, a burning sensation in the throat, throbbing of the blood vessels in the neck and temples, and dryness of mouth with thirst. The pulse becomes rapid and weak and nausea, vomiting and diarrhoea set

Frigate mackerel (*Auxis thazard*) (top) and skipjack tuna (*Euthynnus pelamis*) (bottom) are two of the commercially important clupeotoxic fishes







(Above) Barracuda (*Sphyraena acutipinnis*) is more feared by aqualung divers than the shark because of its utter fearlessness. (Right) Snapper (*Lutianus erythropterus*), a popular fish, is an energetic predator, and hence, like the barracuda, is frequently involved in ciguatera casualties

in. Usually, the symptoms subside within 12 hours, but may sometimes last for as long as a week. Fatality is rare but not unknown.

Treatment consists of evacuating the stomach, and administration of antihistamines such as epinephrine, cortisone and benadryl intravenously. In case of shock, intravenous fluids and plasma will be necessary. Prevention is, of course, better than cure, and any fish with a peppery taste should not be eaten.

Another kind of poison, called clupeotoxin, has, fortunately, not been recorded from India, though some of the fishes which transvect the poison are commonly found in Indian seas. These are the round herring (*Dussumeria acuta*), the Bengalee's favourite hilsa (*Hilsa ilisha*), gizzard shad (*Nematolosa nasus*), Indian sardines (*Sardinella longiceps, Sardinella fimbriata,* and *Sardinella sindensis*), Indian tarpon (*Megalops cyprinoides*), and anchovy (*Thrissina baelama*).

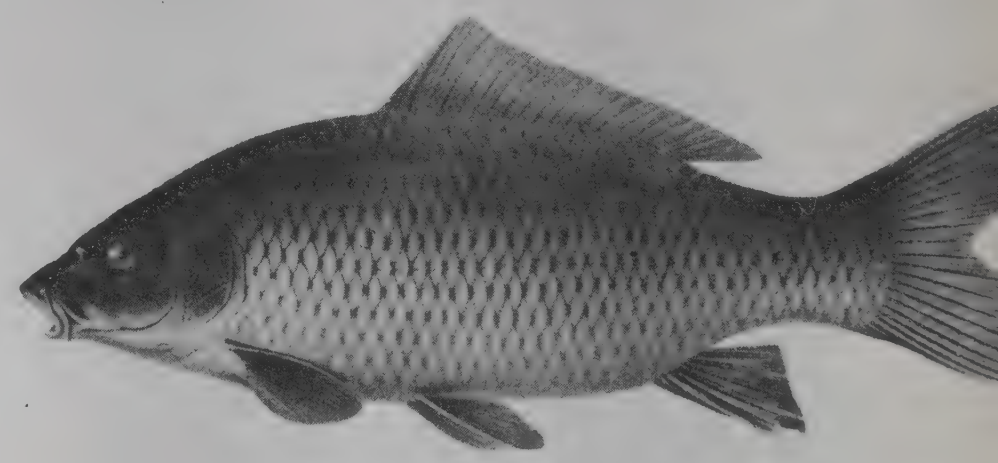
All these fishes are commercially important and thus valuable; yet, at times, they become violently toxic, sometimes surpassing even the effects of puffer fish poisoning in the rapidity of death — a fact that has given rise to the adage, "if you started eating at the head of the fish, you would be dead before you reached the tail." The toxin is similar to ciguatera, and even the symptoms, such as metallic taste, dryness of mouth, nausea, stomachache, diarrhoea and vascular collapse are identical. It is, however, considered different from ciguatoxin because the latter occurs in benthic (bottom-dwelling) solitary fishes, whereas clupeotoxin is found in pelagic (surface-swimming) schooling plankton-feeders. The recorded mortality rate is about 45 per cent of those affected. Unfortunately, there is no way to detect clupeotoxic fishes, as one fish in a shoal may be deadly, while another swimming by its side in the same shoal may be quite harmless. Cooking does not inactivate the poison. Death may occur in less than 15 minutes.

Although there have been no known instances of clupeotoxin deaths in India, it may be of interest to note that in Sri Lanka, the then Governor, in February 1823, banned sardine fishing because of incidents of fatality. The order read: "Whereas it appears by information conveyed to the Government that at three several periods at Trincomalee, death has been the consequence to several persons from eating the fish called Sardinia during the months of January and December, enacts that it shall not be lawful in that district to catch sardines during these months, under pain of fine and imprisonment."

A not so widely known poison, called gempylotoxin, is found in a group of fishes called snake mackerels, more appropriately termed castor oil fish. The hollow bones, such as the vertebrae, contain a clear, thin oil. Although the fishes are widely distributed in the Indo-Pacific regions, they do not occur off India. Inhabitants of the Line Islands call it "*Te icka ne paka*" which, roughly translated, means "the fish that makes you obey the call of nature in double quick time"! The bone marrow, containing the purgative oil, gives rise to diarrhoea, but without abdominal pain or cramps; however, there are no other untoward effects. The principal constituents of the oil are a saturated compound, cetyl alcohol, and an unsaturated compound oleyl alcohol.

Paralytic shellfish poisoning is quite similar to ciguatera in that the animals consumed by man, such as clam, oyster and mussel, by themselves are harmless. It is only after these shellfish ingest certain dinoflagellates, notably *Gonyaulax* and *Gymnodinium*, that they become poisonous to human beings. These dinoflagellates are a regular feature in the seas, but, under favourable conditions of food and temperature, they multiply prodigiously, forming discolorations of the seawater known as "blooms". Since red is one of the commonest discolorations, this occurrence is usually termed "red tide". Like ciguatera, shellfish from areas where they have been eaten for years suddenly become extremely poisonous; they may become safe for consumption again after one to three weeks. This poison from the dinoflagellates is accumulated in the digestive gland (hepatopancreas) and crystalline style — a translucent yellow rod found in the pyloric caecum of the shellfish and containing a starch-reducing enzyme. In the butter clam *Saxidomus*, however, the poison is found in the siphons, and may remain in a bound condition for many months before decreasing to a safe level.

Symptoms of paralytic shellfish poisoning may appear in the victim within an hour, starting with a tingling in the lips, tongue and face, changing to numbness of the extremities. Dizziness, headache and weakness lead to convulsions and muscular paralysis. Death may occur in 12 hours. If the victim survives beyond this period, his chances of recovery are good; average fatality is 8 per cent. The poison, called saxitoxin, has been obtained in pure form, a white hygroscopic powder



European carp (*Cyprinus carpio*) has Ootoxic eggs. But, though widespread in Indian waters now, no poisoning cases are on record

Schizothoracine fishes, a rather poorly known group found in the Himalayan foothills, may contain Ootoxins

ng-nose butterfly fish (*Chelmo rostratus*) s an elongated snout which enables to probe into rock and coral crevices r food

B. F. CHHAPGAR

Blue surgeon fish (*Acanthurus leucosternon*) gets it name from the sharp spines, akin to a surgeon's scalpel, hidden in the fleshy root of the tail. When everted, these can inflict a nasty cut. This is a ciguatoxic as well as a venomous fish

asily soluble in water and stable to eating. (Its chemical formula, as a ydrochloride salt, is $C_{10}H_{17}O_4N_7$. HCl, and its molecular weight is 72.)

Besides the paralytic shellfish poi- ons, a few bivalves, such as oysters, *Tapes*, *Dosinia* and *Callista* are also poisonous. Here, however, the poison is not transvected but is produced in the body of the animal. Callistin is restricted to the ovary of *Callista* and contains a high concentration of choline. Venerupin, found in the other three shellfish named above, is concentrated in the digestive gland (liver). Inasmuch as cases of poisoning have been few and restricted to localised regions in Japan, we need not go into their details here.

Among the gastropods (snails), whelks (*Neptunia*) contain a poison called tetramine, which is concentrated in the salivary glands. Here, too, cases of poisoning are restricted to Japan.

Among the Crustacea, horseshoe crabs contain a poison in their unlaid green eggs, and also in their flesh and viscera, during the reproductive season. Despite their periodic toxicity, these eggs are highly esteemed by Asiatics. The horseshoe crab is also found in the Bay of Bengal.

The sand crab, *Emerita*, is capable of feeding on the dinoflagellate *Gonyaulax* and thus cause ciguatera-like poisoning. It occurs on both the eastern and western coasts of India.

B. F. CHHAPGAR

(Left) Squirrel fish (*Holocentrum rubrum*) is a nocturnal fish, as can be seen from the large eyes. It is also implicated in ciguatera poisoning

A US Senate Sub-committee inquiry two years ago revealed that the Central Intelligence Agency (CIA) had stored large stocks of the deadly neurotoxins, tetrodotoxin (from puffer fish) and saxitoxin (from California mussels) for use by its agents via 'squirt' guns!

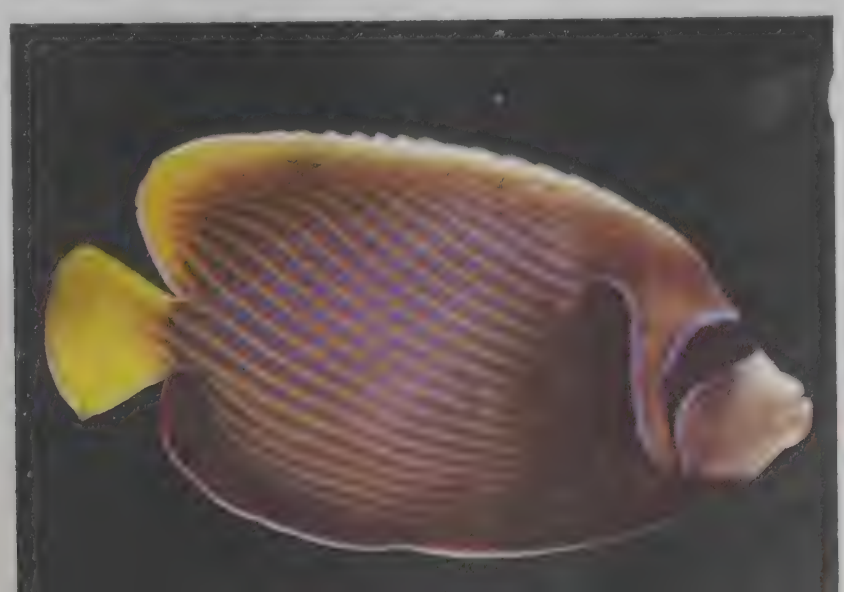
K.P.N.

Although most sea urchins are to be feared for their venomous spines and pedicellariae, there are some poisonous species also. The poison is contained in the ripe ovaries and can be as dangerous as puffer fish poison.

Holothurin, or sea cucumber poison, can give rise to severe contact dermatitis if one touches the sticky filaments which are thrown out, together with the entrails, by sea cucumbers when handled. The same poison, if it reaches the eye, can cause blindness. The poison is a cardiac glycoside or steroid saponin, and, curiously, occurs otherwise only in plants. Sea cucumbers, in the form of *trepang*, are regularly eaten in oriental countries, but the poison is probably hydrolysed into non-toxic products in the stomach.

Several fatal poisonings have been reported from consumption of sea turtle meat. In fact, only a couple of months ago, there was a news report of five persons in Sri Lanka dying

(Below, right) Bluering angel (*Pomacanthus annularis*) shows a design of circular blue bands on a yellow ochre body. (Below, left) Emperor angel (*Pomacanthus imperator*) is another ciguatera transvector



after eating a sea turtle. Turtles, like fishes, appear to transvect ciguatoxin, probably by feeding on ciguatoxic fishes.

Since ciguatoxic fishes are in no way different in appearance from normal fishes, there is no way to distinguish between them visually. There are also no simple field chemical tests to detect a poisonous fish. In some societies, the practice prevails of feeding a suspected fish to a susceptible animal, such as a kitten. In the Pacific islands, it is customary for old members of the family to eat fish, and wait sufficiently long before allowing the children to eat the same fish. Maybe, this is their way of sparing the cream of youth from the dangers of poisoning. Curiously, in former days in the Marshall Islands, certain fishes were forbidden as food to commoners and only the chiefs could eat them.

The biogenesis or the process by which poison originates in the body of a fish is still a matter of speculation. At the beginning of the 16th century, it was believed that fishes became toxic as a result of eating the fruit of the manchineel berry (*Hippomane mancinella*) which fell into the water from trees growing on the seashore. During the 18th century, the poison was attributed to the existence of undersea copper banks. During World War II, the cause was extended to include poisonous cargo, sunk with ships, and then the post-war dumping of toxic war material.

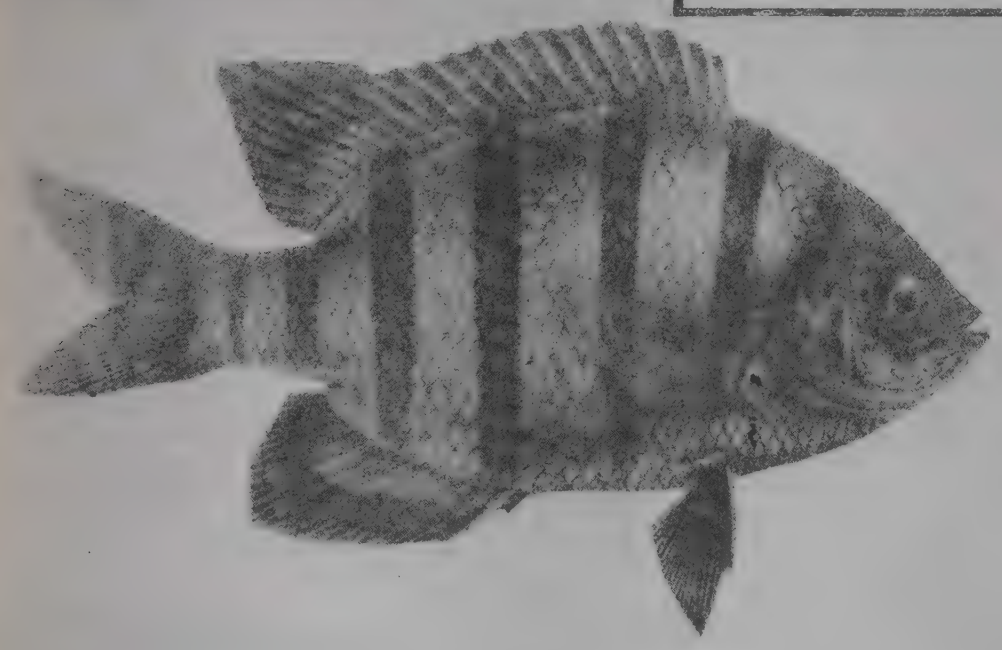
Putting marine poisons to use

A poison is merely an indicator of intense biological activity. In diluted form it might well give a very useful and highly effective therapeutic agent.

Tetrodotoxin is used in Japan as a narcotic to relieve the agony of terminal cancer. Cephalotoxin, from the salivary glands of the octopus, inhibits blood coagulation. Hecoisin, another drug obtained from the same animal, controls high blood pressure and corrects the irregular beating occurring after a heart attack. The poison of a cone shell (*Conus*) is a powerful muscle relaxant, and its active fraction can be used as an anti-convulsant drug. The poison from another *Conus*, which produces a spastic (rigid) paralysis in its victims, might help to contract muscles whose normal excitability has been lost due to injury or disease.

Saxitoxin, since it acts directly on the atrio-ventricular conduction system of the heart, depressing respiration and reducing blood pressure, is a promising anti-hypertension drug. Halosphaerin, obtained from another unicellular alga, is a powerful antibiotic which in nature helps keep the intestinal tracts of penguins remarkably free of bacteria. Holothurin, from sea cucumbers, produces an extensive variety of effects: it inhibits the growth of some protozoa, prevents regeneration in planarian worms, retards pupation in fruit flies (*Drosophila*), produces irreversible nerve deadening (like cocaine), and halts the growth of tumours in mice. All these effects are believed to be due to the poison influencing RNA synthesis, and this fact makes it a promising drug for the treatment of cancer.

B.F.C.



(Top) Sergeant major (*Abudefduf saxatilis*) gets its name from the stripes on its body. (Bottom) The goat fish (*Upeneus indicus*) is named after the 'beard' of two long barbels on its chin. Both fish are involved in hallucinogenic food poisoning

Gradually, a hypothesis has been built up that fishes acquire the poison through feeding on algae, or on other fishes that have fed on algae, especially the blue-green alga *Lyngbya*, the alga *Schizothrix*, or some equivalent poisonous seaweeds, corals etc. The hypothesis is based on the following considerations:

1. There is extreme variability in toxicity even in the same species of fish; no species is universally poisonous all the time. Some species of fishes may be extremely toxic in a given locality, whereas other species in the same locality may be harmless.

2. There is spotty geographic distribution. Fishes on one part of an island may be safe to eat, while the same species on another part of the island may be toxic. This also suggests that such fishes are non-migratory. Ciguatera is, however, restricted to tropic and subtropic regions.

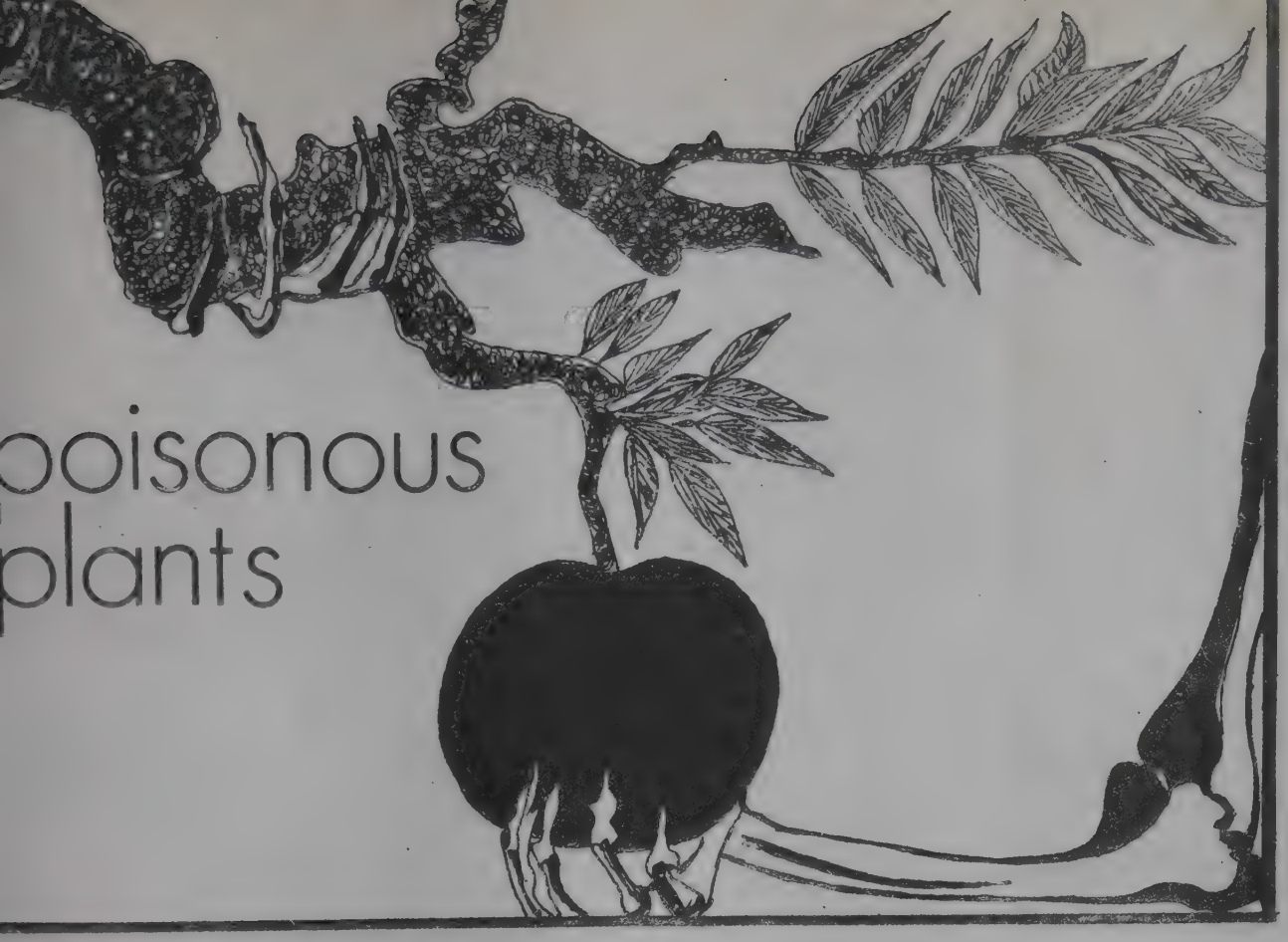
3. A locality that once had toxic fish populations may later become a safe area, or it may be the other way round.

4. The most poisonous fishes are the large predators. When such a predator feeds on a herbivorous fish that has already ingested ciguatoxin within its body, the predator acquires within a short time all the toxin accumulated by its prey over its lifetime. However, once it has acquired this toxin, it takes a very long time for this toxin to dissipate out of its body.

5. A poisonous fish population may suddenly crop up after a storm, earthquake or human activity (dredging, blasting, dumping of material, sinking of enemy shipping, etc). The destruction of established life on the sea bottom, together with the availability of new surfaces, would encourage profuse growth of the organism(s) producing ciguatoxin.

6. Areas of intermittent freshwater entry (river mouths), or heavy rainfall in a shallow, ill-drained atoll, may also kill the normal flora, allowing growth of new forms.

Dr. B. F. Chhapgar (45), former Curator of the Taraporevala Aquarium, Bombay, is Scientific Officer for Aquatic Radioactivity Studies at the Bhabha Atomic Research Centre, Trombay. The sea and its creatures fascinate him and he has swum, sailed, fished and scuba dived extensively in Indian and Sri Lanka waters.



poisonous plants

N. VISWANATHAN

hat fatal and perfidious bark
ilt in the eclipse and rigged with curses dark.

— "Lycidas"

John Milton wrote these "dark" lines on a poisonous plant in 1637, but centuries before, primitive man had cognised the presence of poisonous ctors in the vegetable kingdom. oxic plants found early use as isons for spear and arrow tips in nting, in medicine, and among actitioners of the poisoning art.

In modern times, knowledge of ant toxins is of interest to bota-sts, chemists, toxicologists, ecolo-sts, forensic scientists, and food and ug administration authorities. The udy of toxic plants has often led to teresting compounds and new re-arch tools for use in pharmacology, r instance, the hallucinogens.

Besides the direct effect on the gesting animals or human beings, ant toxins can cause teratogenic fects, that is, they can affect the nborn offspring. Many of the conge-ital deformities in livestock, that ad earlier been assumed to have a enetic cause, are now known to be roduced by plant teratogens.

Poisonous plants owe their toxicity the presence in them of toxic hemicals. Except for a few plants ontaining molybdenum and sele-ium, most of these toxins are organic ompounds. The toxicologist gene-ally assesses their acute effect in erms of LD_{50}, the (lethal) dose vhich kills 50 per cent of the animals ested.

A toxic substance can be classified n one of several ways, according to: (*i*) its physiological manifestations, for instance, as nerve and muscle poison, or as a carcinogen; (*ii*) its chemical structure, like alkaloid or glycoside; or (*iii*) its botanical origin. No single method of classification is fully satisfactory. It has been estimated (*Poisonous Plants of India*, Chopra, et al) that there are in India alone about 700 poisonous species belonging to over 90 families of flowering plants. In this article, which is not comprehensive, we shall survey only some well-known plants and fungi, and the nature of their toxic principles.

Poisonous seeds

The red and black seeds of *Abrus precatorius* L. (Indian licorice or jacquirity) are used by goldsmiths in India as weights and in bead work. A single seed chewed is reportedly lethal for humans, but if the seed coat remains intact, the seed is considerably less toxic. The seeds have been employed in poison darts and daggers.

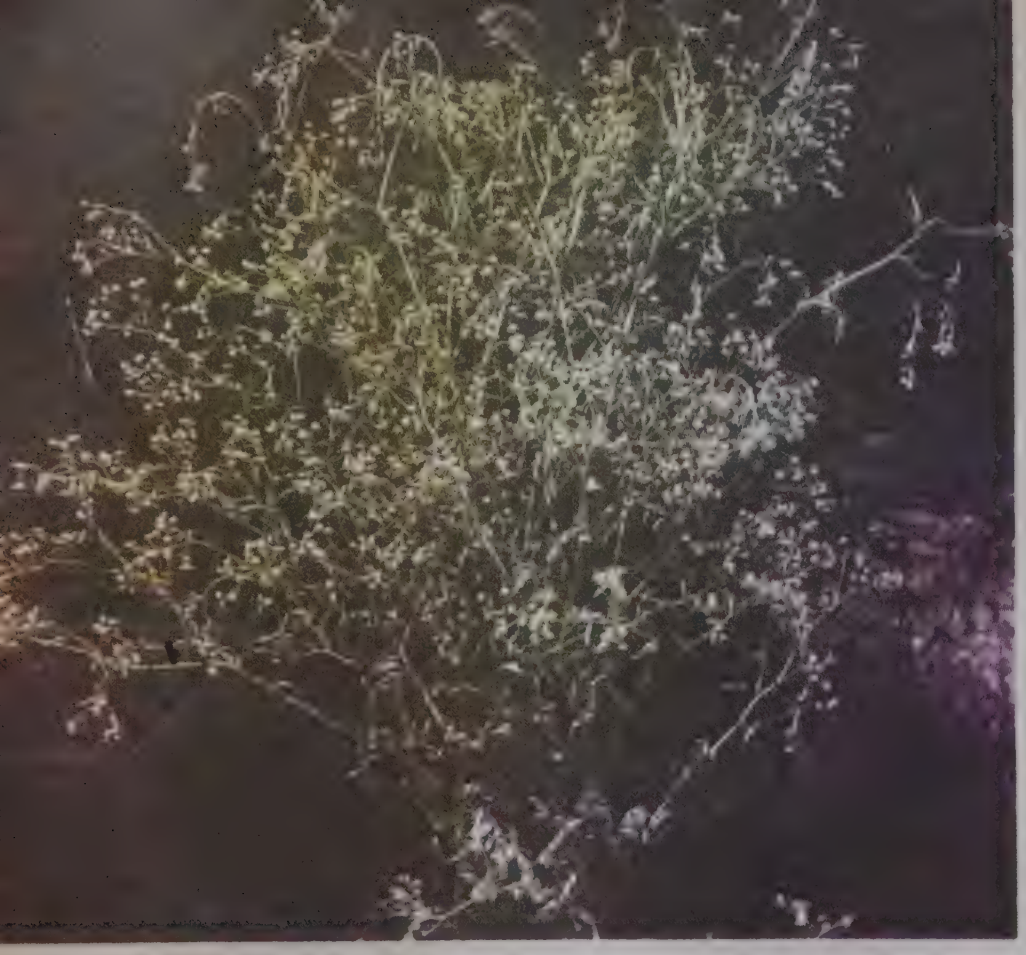
Abrin, the toxic factor in the seeds, is a glycoprotein and resembles ricin isolated from castor seed cake. It has strong haemagglutinating activity (it causes red blood cells to clump together). In human beings, symptoms of poisoning are delayed by one to three days; the symptoms include nausea, diarrhoea, drowsiness, disorientation, cyanosis (blueness of the skin resulting from insufficient oxygen pick-up by red blood cells), stupor and circulatory collapse. Immunisation with anti-abrin serum is considered a practical measure for livestock. Abrin and ricin are more toxic to malignant than to normal cells, and attempts have been made to use them to treat cancer in animals.

Lathyrism or paralysis of the lower limbs caused by "khesari dal" (*Lathyrus sativus*) continues to be a public health problem in India. The crippling disease affects the poorer sections of the people, especially under conditions of famine when khesari dal forms the main part of the diet. The disease affects livestock, too.

Lathyrism shows two pathologic aspects. The first, neurolathyrism, due to *L. sativus*, has been encountered in India for centuries. The ancient Hindu treatise *Bhavaprakasa* mentions that "the triputa pulse causes a man to become lame and it cripples and irritates nerves". The disease is characterised by muscular rigidity, weakness and paralysis of leg muscles. The onset is sudden and mostly affects young men. Medical treatment is unsatisfactory, but vitamin A may give some functional relief. Three distinct neurolathyrogens, all amino acids, have been isolated from the grains. The toxins are almost completely removed by steeping the dehusked seeds in hot water, but, in the process, the B-vitamins are also lost. Besides avoiding khesari dal diet, one approach to the problem is to get hybrids which contain low levels of the toxins.

The second type, osteolathyrism, caused by *L. odoratus* or flowering sweet pea of Mediterranean origin and cultivated in gardens for its flowering plants, is observed mainly in rats and turkeys, but not in man. It affects the spine (causing hyphoscoliosis, a condition in which the spinal column is convex both backwards and sideways) and causes curvature of the long bones. Aortic aneurysms (dilatation) are also observed and this effect has been termed angiolathyrism. The toxin, 8-aminopropionitrile, prevents cross-linking of connective tissues.

Strychnos nux-vomica, the poison nut tree or *kuchla* as it is popularly known, is an evergreen tree, native to India. It is about 12 metres tall, with glossy leaves, small yellowish flowers, and an orange-coloured and shaped fruit. Its seeds contain a very toxic alkaloid, strychnine, whose structure (see p. 45) had baffled organic chemists for decades; it is extremely bitter to taste. On ingestion, strychnine or nux-vomica can cause a violent death. Severe symptoms begin to appear within 10 to 30 minutes; the muscles begin to twitch, muscular spasm occurs and the person falls in a violent convulsion. And as many as 10 convulsions, separated by intervals



S. N. KULKARNI

(Left) *Parthenium hysterophorus,* **popularly known as "Congress grass", causes contact dermatitis. It has spread widely in India in the last few years**

(Right) *Datura metal* **Linn. Datura poison has a notorious history in crime**

of 10 to 15 minutes each, may be experienced, but death due to respiratory arrest following continuous spasm of the respiratory muscles commonly occurs between the second and fifth convulsions.

The treatment consists of consuming activated charcoal followed by intravenous administration of a rapid-acting barbiturate, which depresses the central nervous system. Because it stimulates the nervous system, clinically strychnine has been used as a stimulant in small doses as an antidote for depressant drug poisoning and as an ingredient in tonic preparations.

The related South American *Strychnos* plants, *Strychnos toxifera* and *Strychnos castelnaeana*, are the sources of curare poisons. Curare is also derived from the roots of another plant, *Chondodendron tomentosum* or pareira. The poison kills by causing respiratory paralysis. Curare (meaning "he, to whom it comes, falls") has a fascinating history, as recounted by Margaret Kreig in *Green Medicine*. The Amazonian natives used it in blow guns and arrow poisons. Missionaries and explorers brought it to the attention of European scientists, and Claude Bernard, in 1844, in a brilliant study pinpointed curare's physiological action. It progressively blocks off the nerve endings adjacent to the muscles, first in the extremities, then finally in the chest wall. The brain does not seem to be affected because the victims remain lucid till the end.

Three varieties of curare are known and their classification is based on the nature of the vessels used for storing them. Tube curare, stored in hollow bamboo canes, is prepared from *Chondodendron tomentosum*; it owes its action to *d*-tubo-curarine which is used in medicine as a muscle relaxant. Calabash curare, which is the most potent, is stored in hollowed-out gourds and is made from *Strychnos toxifera*. The bark of the tree is scraped off and macerated in water to obtain curare. More than 50 alkaloids (for example, toxiferine) were isolated from this by Nobel Laureate Paul Karrer at the University of Zuric Pot curare uses *Stychnos castelnaeana* its source. It is stored in clay vesse The natives tested the potency of the preparations by using them on fro — the height to which the fr jumped on injection of curare indic ted the potency of the poison.

Almost no other plant has such history of crime as datura (see "Plant in Crime", December 1967, p. 46, an "Of Poisons and Poisoners", March 1973, p. 41). *Datura stramonium* and *D metal* plants have been used; datur poison is concocted as a brew or te from leaves and seeds of these plants The clinical symptoms of poisonin are thirst, visual disturbance, flushe skin, convulsions, coma and death The toxic ingredients are the tropan alkaloids — atropine, hyoscyamin and scopolamine.

Besides its well-known use in homi cide and robbery, it is reported tha whores in medieval India used datur poison to put inconvenient patrons t sleep. In central America, childre were given *D. sanguinea* seed decoctio

(Left) Seeds of *Abrus precatorius* **Linn, or ghunchi. (Centre)** *Strychnos nux-vomica* **Linn, or poison nut tree or** *kuchla* **as it is popularly known. The seeds yield strychnine. (Right)** *(fly agaric),* **a poisonous mushroom**

S. N. KULKARNI

nd made to walk about during the primary stage of excitement. It was believed that when the effect wore off and the children fell to the ground, gold would be found there. Since here was a large quantity of gold in hat soil, this frequently worked.

The dreaded plants of the *Aconitum* and *Delphinium* families owe their oxicity to complex alkaloids like ycoctonine. In India, the plants *A. heterophyllum* (*ativisha*) and *D. denudatum* (*nirvisha*) are found mainly n the Himalayan region and sepoys of the British army had been mortally wounded by poisoned arrows in military expeditions to Sikkim, Bhutan and Assam. The signs of toxicosis include loss of muscular control, trembling and ultimate respiratory paralysis.

Certain toxic lupine alkaloids (like cytisine and sparteine) account for the toxicity of plants like *Cytisus scoparius* (yellow broom) found in the Nilgiris and *Sophora mollis* (Himalayan laburnum), which grows in the Himalayan region. Ingestion of lupine plants by pregnant cows is responsible for the marked congenital deformities known as "crooked calf disease" (see figure). This condition is characterised by torticollis and scoliosis (lateral curvature of the spine).

Hemlock was immortalised in history as the poison used to kill Socrates; this is derived from the plant *Conium maculatum* (spotted Hemlock), and owes its toxicity to coniine and related piperidine alkaloids which cause respiratory paralysis. The fruits contain as much as two per cent of the alkaloids; other parts contain less.

Plants of the *Senecio* and *Crotalaria* species contain hepatotoxic (toxic to the liver) pyrrolizidine alkaloids. *Senecio vulgaris* or groundsel is found in the Nilgiris and in the mountain tracts in India, and *Crotalaria juncea*, the Indian hemp, is cultivated for its stem fibre. Poisoning from both *Senecio* and *Crotalaria* plants is not a serious problem in India, but in northern Australia, they are responsible for the "walk-about syndrome" observed in horses; the horses begin to stagger and roar before ultimate death. Some of these alkaloids (for example, heliotrine) are teratogenic; they cause malformations of the ribs and palate, and can pass into the milk of cattle that graze on the plants.

Steroidal alkaloids are the toxic factors of many *Solanum* and *Veratrum* species. Solanine, the toxic glycoalkaloid, is present in the green unripe berries of *S. nigrum* (black nightshade or *kakmachi*) which are eaten in parts of India. It also accounts for 'potato poisoning' in people consuming green tubers, tuber peel and blossoms of potatoes (*S. tuberosum*). Boiling and cooking, however, destroy most of the alkaloids. *V. californicum* causes cyclopism (a malformation with a single eye) in lambs born to ewes that ingested the plant on the 14th day of gestation.

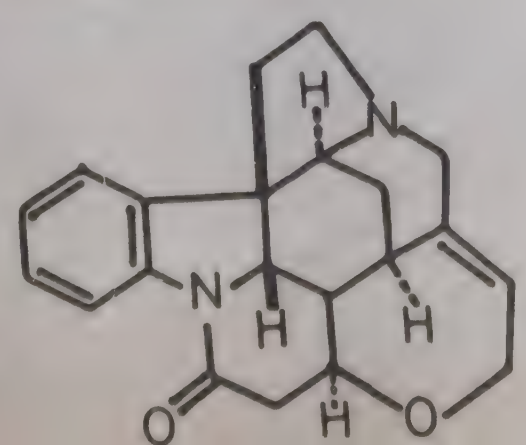
Argemone oil, an oil derived from the seeds of *Argemona maxicana* L. (Mexican poppy or *katakar*) is often found as an adulterant of mustard, sesame or groundnut oil. The toxic factor in the oil, sanguinarine (an alkaloid) interferes with the end stages of carbohydrate metabolism. Chronic consumption of such adulterated oil may lead to conditions similar to dropsy (accumulation of fluid in any part of the body); it also causes liver enlargement and pulmonary congestion.

Cleistanthus collinus (*odaichi*, in Tamil) is a highly poisonous plant found in several parts of India, particularly in Tamil Nadu. In fact, the leaves have been used for suicidal and homicidal purposes. The toxic constituent has been identified as a lignan lactone cleistanthin.

Cyanogenic glycosides occur widely in the plant kingdom. They owe their toxicity to the hydrogen cyanide liberated from the glycosides by enzymes or dilute acids. Three distinct glucosides identified in edible products are amygdalin in bitter almonds, dhurrin in sorghum and prunasin in wild black cherry. Immature bamboo shoots, a delicacy in many countries, are rich in cyanogenic glycosides. Wild black cherries, tapioca and sorghum are responsible for extensive livestock deaths. Repeated intake of sublethal doses of cyanogens can cause blindness (amblyopia). Cyanogenic plants must be washed well in running water and should be rejected if found bruised as the enzyme is released at the site and hydrogen cyanide gets accumulated. However, boiling destroys the toxins.

Cardiac glycosides, which affect the heart, occur in plants like *Digitalis*, *Apocynum* and *Asclepias* (milkweed) species. Symptoms of poisoning in livestock include loss of muscular control, staggering, spasms and paralysis.

Strychnine structure



COURTESY: R. F. KEELER (*Lloydia*)

Congenital deformity in livestock from maternal ingestion of *Lupinus sericeus*

A large number of plants are known to cause allergic contact dermatitis or allergic skin reactions. The most infamous of these is probably *Parthenium hysterophorus* ("congress grass") brought to India in 1956 from the Americas. It has been the cause of a serious outbreak of eczema in Poona and its neighbourhood, and in Bangalore. The allergic compounds in this aggressive weed are parthenin and ambrosin (sesquiterpene lactones). Recent electron microscope studies of the leaf surface show the presence of four types of glandular and non-glandular plant hairs. These contain the allergens. Allergic skin reactions like rashes and blisters on the hands, face and ears result when the glands rupture and deposit the lactones on the exposed skin. The abundance of hairs on wind-disseminated dried plant parts accounts for dermatitis even in people who do not come in direct contact with the plant. The weed poses a serious ecological problem and physical destruction has proved infructuous.

Besides toxins of higher plants, there are several "mycotoxins" produced by a variety of fungi that infect plants. Although their acute symptoms are dramatic, chronic effects may be more important because they are insidious and difficult to detect. Mycotoxins can be produced on grains in the field, during harvest and processing, and during storage. The problem is worldwide.

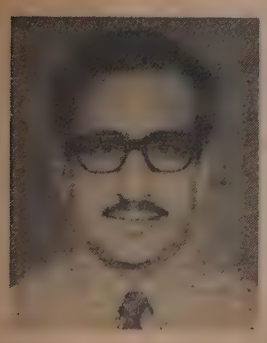
Ergotism caused by the fungus *Claviceps purpurea* which infects rye and wheat leads to gangrene and a form of mania described as St. Anthony's Fire. The toxins in the fungus are alkaloids, some of which find use in medicine as uterine stimulants and for relief in migraine headaches. Aflatoxins, produced by *Aspergillus flavus* and *A. parasiticus*, are hepatotoxic and carcinogens. They are often found in groundnuts and can be eliminated only by autoclaving or by alkaline treatment.

Kodomillet (*Paspalum scrobiculatum* L., *harik* in Marathi) is a minor gram crop which has been cultivated in India since ancient times. The grains have often been reported to cause poisoning in man and animals; the ancient text *Arthasastra* describes its use as a poison for tigers. The main symptoms of 'kodo' poisoning are unconsciousness, delirium with violent tremors of the voluntary muscles and vomiting. The poisonous principles have now been traced to the fungus *Phomopsis paspalli*, Pendse and Kanitkar, which often infects the grain. The toxic constituents have been identified as cytochalasins.

Poisoning from toxic mushrooms has been known (see SCIENCE TODAY, July 1973, p. 42) for ages. Most fatal cases are caused by *Amanita phalloides* or death cap; their toxicity is due to cyclic polypeptides. Poisoning symptoms appear six to 15 hours after ingestion; these include gastroenteritis and cardiovascular collapse. Death occurs within five to 10 days from liver failure, and there is no satisfactory treatment for the symptoms. The mushroom may be white, yellow or even blood red in colour.

The mushroom *Amanita muscaria* (fly agaric) causes abdominal pain, intoxication and bradycardia (slow heart action), but most patients recover. The toxic agent was initially suspected to be muscarine but recent work has shown that the neurotoxins are ibotenic acid, muscimol and muscazone. Fly agaric has stimulatory and hallucinogenic properties, and these pass into the urine. For this reason, reportedly during times when the mushroom was not available in abundance, urine from an individual who had consumed the mushroom was drunk to produce the hallucinogenic effects.

The above account highlights the fact that diverse chemical constituents are responsible for the toxicity of poisonous plants. The expressions of acute poisoning by plants are not as violent and dramatic as by animal venoms and marine toxins. What is more commonly observed are the subtle effects produced by prolonged ingestion of a given plant. Such effects, arising out of toxic components that find their way into our food and feedstuffs, can cause disease in both humans and animals.



Dr. Viswanathan (42) is with the Natural Products Division of the Ciba-Geigy Research Centre, Bombay. His special field of study is the chemistry of plant products — alkaloids, terpenoids and oxygen-heterocyclics.

SUSHMA

# of fangs that kill...

M. B. BHIDE
S. B. BHISE

Of the 2,500 species of snakes all over the world, only 400 are known to be definitely poisonous. Man has always considered snakes as hostile animals, but there has been a general ignorance and fear about the possible effects of snake bites, which is more a rural problem in the tropical countries. An old estimate states that every year about 2,00,000 persons are bitten by snakes, of whom about 15,000 die.

In all scientific studies with venom, two questions have received much attention — what is venom, and what effects does it produce in human beings? Snake venom are actually a specialised complex saliva that contains many proteins (particularly specific enzymes and basic polypeptides) called toxins. Two functions are ascribed to it: one is immobilisation of prey, and the other, the initiation of digestion.

Snake envenomation symptoms can be studied on the basis of different groups of snakes. The four major families of poisonous snakes are: Hydrophidae (sea snakes); Elapidae (land snakes like the cobra, krait, etc); Viperidae (land snakes like the Russel's viper); and Crotalidae (like rattle-snakes, not common in India). (See SCIENCE TODAY, November 1968, p. 31.)

Of these, Hydrophidae venoms are myotoxic (they destroy muscle protein or myoglobin) to human beings and cause myoglobinuria (appearance of myoglobin in urine). Elapidae venoms produce symptoms of neuromuscular blockage and mainly cardiotoxicity, without pronounced effects on the blood coagulation mechanism. Crotalidae and Viperidae venoms predominantly affect the blood coagulation system; they are not much known for their neurotoxic effects, and their effects are delayed.

Two assumptions dictate our attitude in dealing with snake bites — one, that bites from venomous snakes are frequently fatal, and the other, that, if no poisoning symptoms are visible, the bite must have been inflicted by a non-poisonous snake. Both are wrong. Even where a bite is from a poisonous snake, there are other factors like venom yield and the amount of venom injected into the victim's body which decide whether poisoning symptoms will follow or not. Hence a poisonous snake bite is not the same as snake bite poisoning.

Snake bite symptoms

Clinically, the most common feature of snake bites is fright: the fear of rapid death. Frequently, emotional symptoms totally dominate the clinical features, and even a placebo injection (that is, containing no therapeutic agent) can dramatically improve the situation. Interestingly, F. Wall (1913) had reported a number of cases where victims bitten by non-poisonous snakes remained unconscious for several hours. In a case of true poisoning, however, local and systemic symptoms can clearly be expected.

What are the local symptoms in a nake bite? Pain follows cobra and iper bites; the pain may last several ays. Swelling is another local symp- om in cobra and viper bites, and is a aluable diagnostic sign. The swelling nay continue to increase for 24 to 72 ours after the bite. In cobra nvenomation, swelling starts im- nediately after the bite and reaches maximum within 24 to 48 hours, ut swelling is more common with iper bites. In viper bites, the red lood cells and plasma escape from he blood vessels into adjoining sub- utaneous tissues causing discoloura- ion. Poisoning from krait bite does ot usually cause local swelling. Blisters, necrosis (deadening of parti- ular body tissues) and bacterial in- ections constitute other local symp- oms. Blisters are more common with iper and cobra bites (see SCIENCE TODAY, June 1974, p. 51).

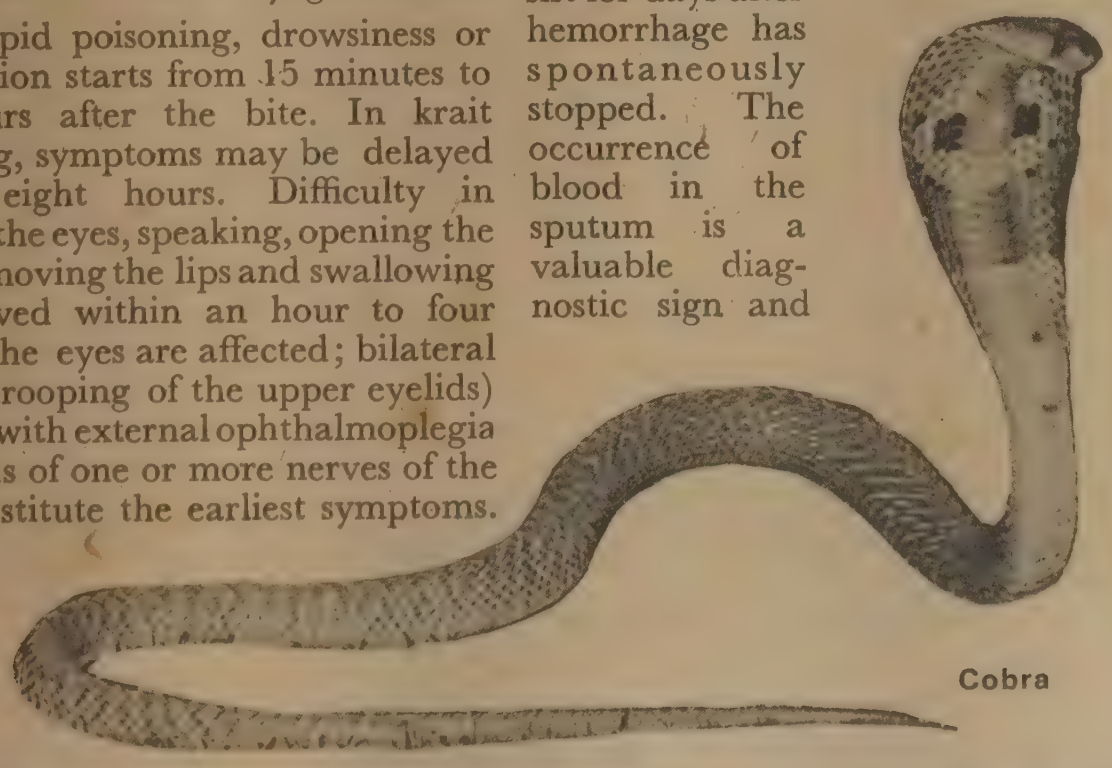
Snake bites of Hydrophidae, Ela- idae and Viperidae produce distinct ystemic effects. Myoglobinuria esulting from hydrophid poisoning is lue to the widespread skeletal muscle lamage caused by the venom. The victim, however, dies of respiratory paralysis (caused by peripheral neuro- muscular blockage). Sea snake bites are painless and cause no local ymptoms (see p. 35). An interesting eature of sea snake venoms is that unlike human beings, experimental animals do not show myoglobinuria.

In elapid poisoning, drowsiness or ntoxication starts from 15 minutes to five hours after the bite. In krait poisoning, symptoms may be delayed up to eight hours. Difficulty in opening the eyes, speaking, opening the mouth, moving the lips and swallowing is observed within an hour to four hours. The eyes are affected; bilateral ptosis (drooping of the upper eyelids) coupled with external ophthalmoplegia (paralysis of one or more nerves of the eye) constitute the earliest symptoms.

In severe poisoning, the patient may not be able to turn the head or the trunk to the side. Flaccid limb paralysis usually affects proximal muscles. Complete limb paralysis, however, never occurs.

Concomitantly, some cardiovascular symptoms are also observed. In severe cobra poisoning, cardiovascular depression is shown by sweating and cold extremities. Tachycardia (abnormally rapid heart beat), feeble pulse and hypotension may also be observed. (Electrocardiogram shows the effect on the ST-segment and the T wave.) These cardiovascular effects usually dominate neurotoxic effects in cobra poisoning. In krait poisoning, however, cardiovascular depression has not been recorded. Other symptoms like urticaria (nettle-rash) and fever may also be observed if antivenin is not administered.

Hemorrhage is the outstanding symptom in systemic viperid poisoning. It is probably due to damage caused to the vascular endothelium (lining of the blood vessels). Clotting defects accompany hemorrhage, and may be an aggravating factor. (The hemorrhagic factor in the venom can be biochemically separated from the coagulation-affecting factor.) Clot formation is an important sign of systemic viper poisoning and, in the absence of specific antivenin administration, may persist for days after hemorrhage has spontaneously stopped. The occurrence of blood in the sputum is a valuable diagnostic sign and should be checked by asking the patient to cough hard and spit. The victim may also vomit blood and pass blood in urine, but these symptoms are less common. Profound apathy, persistent thirst, rapid thready pulse, increased sweating and hypotension



Cobra

Eye movements may be impaired and the victim may have double or blurred vision; pupils are often dilated. Speech may be indistinct due to palatal paralysis. Thirst and vomiting may be other early symptoms. General pain, specifically abdominal pain, may be severe in krait bites. Weakness in the limbs usually develops last. Increasing difficulty in clearing frothy and viscid secretions, which may drool out from the mouth, may follow. Breathing becomes increasingly difficult.

Krait

OF "DRY" BITES AND CURES

It is widely believed that a snake bite is invariably fatal. Not only are the majority of the snakes non-venomous, but even in venomous bites, only 50 per cent develop moderate to serious symptoms. And only a fraction of these are fatal. We have seen several bites from snakes such as the cobra which proved to be "dry".

Although effects of a snake bite depend somewhat on the build and health of the victim, the quantity and toxicity of the venom are what count. Venom toxicities vary considerably; the quantity is entirely regulated by the snake (possibly, depending on the purpose of the bite or the snake's physical condition). Since the amount of venom injected is unknown, the experienced doctor treating a snake bite has antivenin available for as long as the systemic symptoms, like the onset of paralysis in cobra and krait bites and blood in sputum and urine in viper bites, persist.

Of the many purported snake bite remedies, none is the true "miracle" drug except the antivenom serum. It is amazing to see the sudden rallying of a cobra bite victim after an intravenous injection of this serum — from numb paralysis to normal easy breathing in a matter of minutes. The other hundreds and thousands of remedies were mostly conceived of during the pre-antivenin days. They are still popular because information about and supply of antivenin is still not adequately disseminated in rural areas, where snake bites are common. At least, the rural primary health centres should keep the antivenin handy.

Maybe, many of the remedies were somewhat scientifically conceived. For example, potassium permanganate will neutralise venom in a test-tube. One will even now find first-aid guides advising one to rub potassium permanganate crystals into the site of the bite. This "clever" move will only help force the venom into the system faster and possibly destroy tissues at the wound. The venom does not stick around to be neutralised thus.

ROMULUS WHITAKER

[Mr. Whitaker is Honorary Director of the Madras Snake Park Trust and Conservation Centre at the Guindy Deer Park in Madras.]

may develop. Hemorrhage may last less than a week, while blood coagulation may last four weeks (see SCIENCE TODAY, July, September and December, 1970).

Death is rapid after cobra bites and most protracted after viper bites. It is argued that the rapid death from cobra bites may be due to the quick absorption of the venom compared to bites from viperids. The reported minimum and maximum time of death after a snake bite are 15 minutes and 4½ days, respectively.

If the poisoning is not severe, the victim may recover either on his own, or on antivenin administration. Systemic effects, too, are neutralised in such cases, but local symptoms, especially necrosis, may continue for a longer time — two weeks to one month, or even two to four months. Swelling may subside after two to three weeks at the earliest, or it may last two to three months.

Treatment of snake bites

When a snake bite victim approaches a clinician, the latter has to decide about three problems: (1) is the amount of venom injected significant? (2) is systemic poisoning present? and (3) was the bite from an elapid or a viperid snake? The use of antivenin is advisable only if there are signs of systemic poisoning. Otherwise, supportive therapy is sufficient.

Clinically, local swelling is a paramount indication of venom injection. If local swelling is absent two or more hours after the bite, it rules out significant envenomation by vipers and cobras. Systemic poisoning is indicated by drooping of the upper eyelids, shock and local swelling in cobra bite, and by the presence of blood in the sputum in viper bites. Krait bite, however, shows none of these features.

The treatment of snake bite consists of first-aid, supportive therapy and specific antivenin. In first-aid, it is advisable not to incise roughly to create a bigger wound; this increases the chances of bacterial infection. A firm, and not tight, ligature (tourniquet) should be fixed (see box on p. 50). If emotional features dominate the clinical picture, a prompt placebo injection may help dramatically. Systemic antibiotics may be given, if necessary, to check bacterial infection. To relieve the pain, mild analgesics like aspirin, acetaphenetedin, codeine or meperidine may be given. Tetanus antitoxin should never be routinely given as it is prepared from horse serum and may complicate the therapy as antivenin also contains horse serum. Steroids may be given, if necessary, only to treat delayed serum reactions.

In treating respiratory failure in cobra bites, aspiration of secretions by insertion of an endotracheal tube may help. Atropine can reduce the secretions. It may be necessary to force oxygen into the lungs intermittently through artificial respiration. (If artificial respiration cannot be done, then manual compression of the rebreathing bag from an anaesthetic machine should be tried.) In modern hospitals, use of artificial lungs can replace all these arrangements. Heparin has been found to save life in viper bites in experimental animals.

The crucial remedy, however, is the specific antivenin. In India, the Haffkine Biopharmaceutical Corporation, Bombay, and the Central Research Institute, Kasauli, manufacture and supply polyvalent antivenin, which is active against venoms of cobra, Russel's viper, common krait and saw-scaled viper — the most common poisonous snakes in India. The antivenin is a lyophilised (powder form), processed horse serum, hyperimmunised with individual venoms. Though rabbits, sheep, mules and horses can be used for the preparation of antisera, horses are particularly preferred because: (*i*) of their build (and, therefore, the availability of a greater amount of serum), (*ii*) they harbour very few zoonotic diseases (diseases which can be transmitted from animals to man), while cattle can transmit several diseases, and (*iii*) horses are easy to bleed while standing. Diluted venoms from the four snakes mentioned above are injected at regular intervals into the horse in increasing doses for eight months to a year. This provokes the production of antibodies in the horse serum. After checking the strength of the serum, the horses are bled for four to six years. The plasma is separated from the blood, concentrated, purified and lyophilised (processed into powder form).

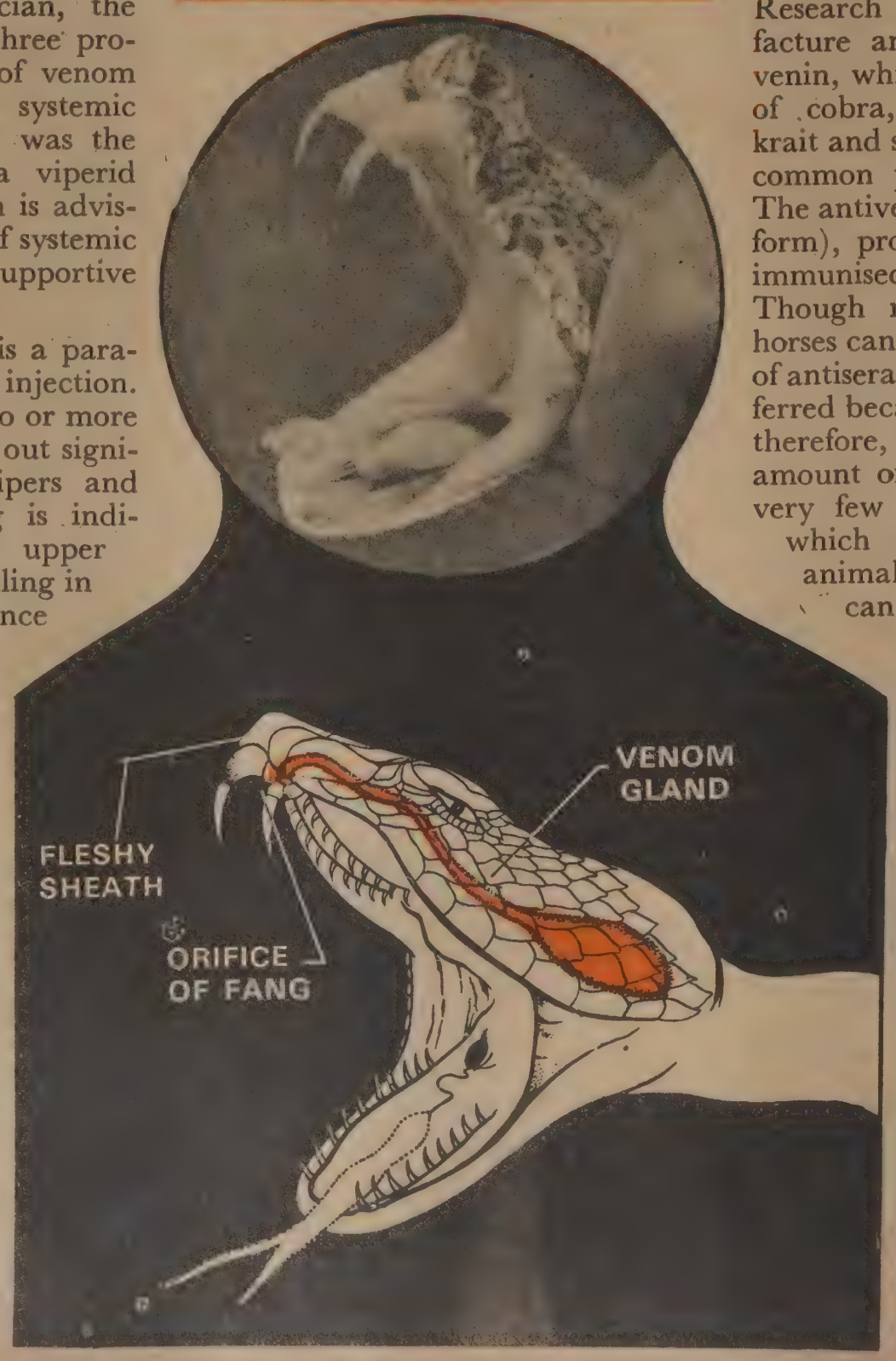
The antivenin is given either as an intravenous

A MAMBA BITE SURVIVOR

If there is a rule for the safe handling of venomous snakes, it is, "don't take your eyes off the snake's head, and don't get distracted". Yet, snake handlers eventually get bitten. But the snake that bit Jack Seale, a South African snake expert, a few months ago was no ordinary one — it was a black mamba, the most dangerous snake known. Its bite can kill a person in five minutes, and there is no record of anyone surviving a full mamba bite.

But Seale survived, brought back from the brink of death. Seale kept his cool, and acting quickly, he cleaned the wound, injected himself with heavy doses of antivenin and was rushed to a hospital 45 minutes ride away. By the time he reached the hospital, Seale was slipping into a coma, but then he remembered the experiments one of his friends at the Johannesburg University was conducting, in which rabbits survived lethal envenomation after they were kept alive on artificial lungs.

Seale told the doctors to put him on artificial lungs. As Seale was kept alive for the next six days, his wife and the doctors were not aware that he was conscious, though totally paralysed. And when the doctor said he wanted to drain Seale's blood, Seale "wanted to scream, but couldn't flicker an eyelid". Eventually Seale recovered, after the sixth day. K.P.N.

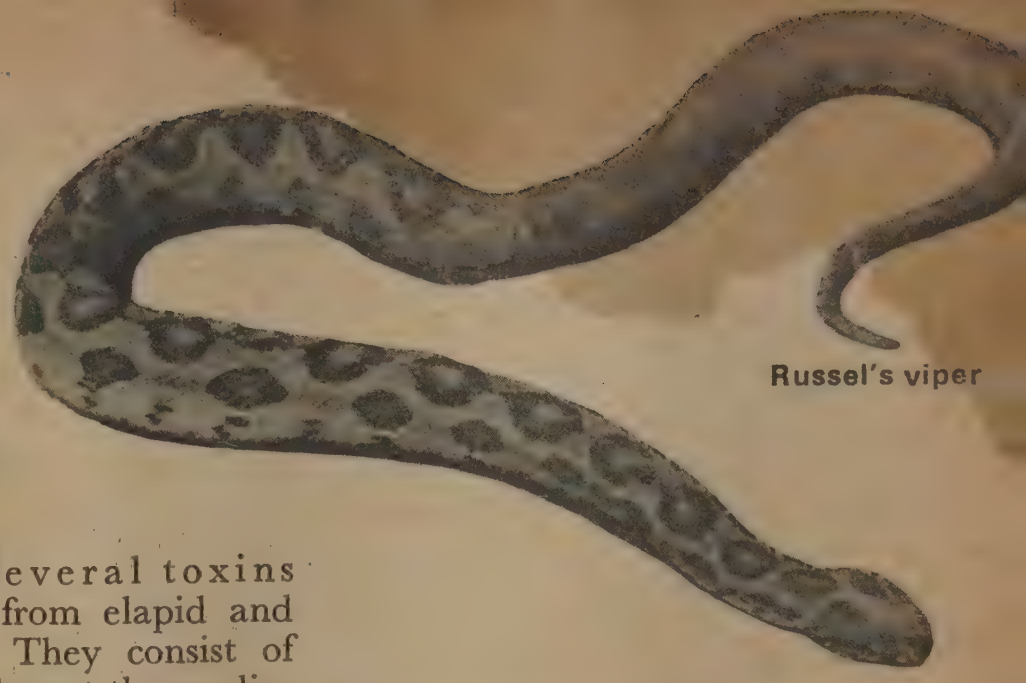


njection or as intravenous drip. efore injecting the antivenin, is advisable to test the victim's erum sensitivity by injecting 0·2 ml f antivenin (as some persons may be ensitive to horse serum). If the victim s sensitive, the antivenin should be iven in graded doses, and a supplementary antihistaminic should be dministered. Depending on the everity of symptoms, 50 to 100 ml ntivenin should be administered (see ox on p. 50).

The antivenin against land snakes s not useful for sea snake bites. The Commonwealth Serum Laboratory, Australia, makes specific antivenin gainst sea snake venom. If the specific antivenin is not available, hemodialysis (drawing out the blood and clearing it of the toxins in the dialysis machine) can save a victim's life.

Some Chinese scientists have claimed that trypsin, an enzyme which degrades proteins, can be more effective in treating envenomation than antivenin (see SCIENCE TODAY, January 1976, p. 9) which is rather expensive; trypsin breaks up proteins and renders it inactive. But this may not be useful because trypsin will also destroy body proteins and cause more complications.

Antivenin is very specific against venom. It combines selectively with the venom and suppresses its toxic actions. However, if the venom has already damaged the tissues, antivenin will not hasten their repair. Saw-scaled viper venom, and to some extent viper venom, damage local tissues severely, and antivenin given late is of little use. So the time gap between the bite and antivenin treatment is important in saw-scaled viper, and to a lesser extent, viper bites. In animal experiments, it has been shown that antivenin reverses the neuromuscular blockage quickly.



Russel's viper

Chemistry and uses

Several toxins have been isolated from elapid and hydrophid venoms. They consist of basic polypeptides. Except the cardiotoxin in cobra venom, all of these roughly resemble d-tubocurarine in their neuromuscular-blocking properties. Another class of toxins, exemplified by β-bungarotoxin, acts solely by blocking presynaptic mechanisms, that is, by blocking the release of acetylcholine at the nerve endings.

Various enzymatic activities have been detected in crude venom, and a few of them have been isolated as well. Of these, "phospholipase" seems to contribute both to hemolytic as well as neurotoxic activity. Other enzymes detected in snake venoms are cholinesterase, L-amino oxidase, hyaluronidase, phosphomonoesterase, phosphodiesterase, nucleotidase, endonuclease, transaminase, etc.

The isolation of the "neurotoxic" and "cardiotoxic" components from snake venoms and their studies in experimental animals have shown that the neurotoxic component acts mainly peripherally, and the respiratory paralysis caused by the venom is not mediated through the central nervous system. The mechanism of how the cardiotoxin causes the heart block is still being studied.

One of the future avenues in venom research is the destruction of toxicity of the venom, without affecting its antigenicity, by irradiating the venom. This can provide a tool which, at least in a limited sense, can be used for active immunisation of the persons who usually handle snakes.

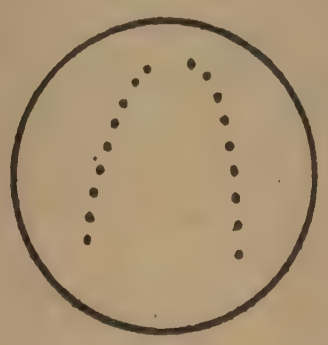
With its wide-ranging actions, it is natural that efforts have been made to make therapeutic use of snake venom. Cobra venom is, for instance, used in chronic pains of nervous and muscular origin, arthritis and in inoperable malignant diseases. Its use has also been indicated in epilepsy (Deoras, P. J., *Snakes of India*). Russel's viper venom is a hemostatic, and its use by dentists in stopping excessive bleeding has been reported. Besides these reported uses, two specific drugs are manufactured from snake venom—Cobroxin and Nyloxin. Cobroxin is claimed to be a more effective analgesic than morphine. It is non-addictive and has no tolerance. But these claims have not been substantiated. Nyloxin is cobra venom along with silicic and formic acids. It is said to be useful in arthritic pains. In England, a drug, Avertin, containing enzymes from the Malayan pit viper, has been claimed to dissolve the clots formed.

Saw-scaled viper

isonous snake bites leave two fine punctures or fang marks (below, left: fang marks in a w-scaled viper bite) at the site of the bite. The gap between the two punctures may vary cording to the age of the snake. At times, there may be only one puncture, or only a scratch. In poisonous snake bites, the symptoms are felt within 10 minutes or so.

In the case of a non-poisonous snake bite, there are several teeth marks (below, right), and the bite is always so severe that the wound bleeds profusely, with flesh coming out of the skin. At times, the snake may hang on with a powerful biting grip and one has to disengage its head physically.

COURTESY: DR. (MRS.) S. M. SANT



SNAKE BITE TREATMENT

First-aid is most important in a poisonous snake bite. The immediate measure is to stop the venom from getting into circulation (see SCIENCE TODAY, December 1970, p. 46 and June 1974, p. 51) by tying a tourniquet. A single ligature with moderate pressure is sufficient to stop blood flow in the veins; an elastic band, a piece of cloth, a handkerchief or any other available material may be used. But the ligature must be put on the single bone portion of the limbs, on the upper arm or on the thigh, and not just above the bite if it is on the lower arm or leg.

Reassure and calm the patient. Restrict all his movements and keep the bitten limb still; movements help speed up venom absorption. The patient should be carried or transported in a vehicle to medical aid immediately. The wound may be dressed up with loose bandage with an antiseptic ointment.

Antivenin injection may be given intramuscularly or intravenously. The treatment should continue till the symptoms subside. It is preferable to administer the antivenin in the following way. The antivenin comes in fine powder form (lyophilised) in ampoules, each ampoule with another 10 ml ampoule of distilled water. The powder and the distilled water are to be mixed. The reconstituted serum should be mixed in a five per cent glucose-saline solution and should then be given by intravenous drip, at 60 to 80 drops per minute.

For cobra bite, eight to 12 ampoules of antivenin may be mixed with 500 ml of saline solution. For viper and krait bites, four ampoules in 500 ml saline solution and, for saw-scaled viper bites, two ampoules in 500 ml saline may be given.

Some doctors may prefer to give two ampoules at a time intramuscularly on the upper portion of the hips or gluteal muscles and rush the patient to the nearest hospital where good facilities are available, or repeat the injection till the symptoms subside. In any case, it is important to do the sensitivity test.

Antivenin is distributed to all panchayats through the zilla parishads. Doctors in the mofussil areas do generally keep antivenin, or they rush to the village dispensary and get the injection. In big cities, however, medical practitioners do not keep these injections; the patients are directly rushed to the general hospitals. Some doctors also feel hesitant because of the possible anaphylactic shock from serum treatment.

The antivenin can be stored in a cupboard in any home at normal room temperature, but if facilities permit, it may be stored in a refrigerator. It remains good for five years, stored either way. But it should not be exposed to extremes of temperature or direct sunlight. An ampoule of antivenin costs Rs. 18·90 at the Haffkine Institute.

N. E. VAD

Some comments could be made on the future use of venoms. Cobra venom has shown promise in the treatment of amyotrophic lateral sclerosis known as Lou Gehrig's disease (disease characterised by spastic limbs). Enzymes from krait venom may find use for myasthenia gravis (muscular weakness). Some fractions of cobra venom are said to have immunosuppressant properties; this may make its use possible in reducing damage in myocardial infarction by inhibiting antibody production against the dead heart muscle. The use of cytotoxins from cobra venom for treating cancer is being studied at the Cancer Research Institute in Bombay.

The purified bungarotoxin has its use in locating acetylcholine receptors to which it specifically binds. Studies with synthetic cobra venom is a promising new approach. Another interesting question with possible future implications is whether serum from snake blood itself has any protective value against its own venom, and, if so, whether it can be therapeutically exploited. According to von Heyningen, "Poisonous snakes are immune to their venoms and to those of allied species. The immunity appears to be different from that which is actively acquired in mammals. It is thought to depend largely on enzymes which destroy the poisons by a process which is not understood." (*The Proteins, Vol. 2, part A.*) Yet, despite von Heyningen's assertion, there appear to be some indications of such a possibility (see SCIENCE TODAY, July 1976, p. 25). With continuing research, snake venom may become a therapeutic boon rather than a distressing problem.

Dr. Bhide (43) is assistant director in charge of pharmacology at the Haffkine Institute, Bombay. Besides snake venoms, his major fields of interest include marine toxicology and indigenous drug research.

Mr. Bhise (25) is an M Pharm research student at the Haffkine Institute. Pharmacological studies in the venom of *Hydrophis cyanocintus* is the subject of his research.

TRUE OR FALS

Snakes have been an integral of almost all cultures giving rise myths, legends and often m misconceived notions in the mi of the ignorant populace. Cou priests and medicine men h exploited this ignorance o countless centuries. Now t scientific studies are beginning separate the chaff from the whe here's a glimpse of what scien has found about some of more commonly held beliefs. .

Can a cobra recognise an individ and take revenge?

Normally a cobra will not attack its own unless it is cornered, provok or trodden upon. While killing ordinary snake, if the hit is missed, snake will run away and take shelter any nearby hideout for its own protecti Later, after the attackers have gone, snake will go on its own way. But so with a cobra. It remains there, in hiding place, and to give vent to its ra it springs out to attack any individual animal or even a vehicle passing by side of its hideout. There is no authen record that the cobra can recognise particular individual who had disturb it earlier and charges him to bite. Du an encounter with the cobra, if the is missed and it escapes and hides, is invariably found in the vicinity within a radius of say, 15 metres, if area is scanned. These enraged attac may be attributed to the greater develo ment of the brain (cerebellum) in cobra than in other snakes.

Cobras can be charmed by musi

Snakes cannot hear. They have external ears (pinnae) and cannot ca the sound vibrations from the air. Ho ever, they do have the internal ear (tympanum, columella auris). The co does not nod or dance to the tune of flute. Being an extremely alert animal responds to the body *movements* of snake charmer and the thudding of feet. If the charmer sits motionless, cobra will remain motionless. This w noted by the author when a charmer w called to take a cobra out of its hide in the snake farm at the Haffkine Institu The charmer played on his instrument half an hour but no cobra came out.

In another incident, a charmer claim to have charmed a snake out of its hidi place in the garden of a house at Band a Bombay suburb. The author examin the snake and found that it was not common species found nearabo Bombay (it was a *Diadima* sp). T most plausible explanation was, snake must have been released from charmer's basket in the garden and th was caught later by the charmer w knew its ways, being its keeper.

Cobras are the protectors of weal or old houses

In olden days, it was the practice

beliefs and misbeliefs about venomous snakes

odgrains and some valuable and nt material in the basements *talghar*, etc). Because such places frequently visited, they afford a nd safe hiding place for rats s). And these rodents are the od for the snakes. Cobras seem quiet secluded places much more her snakes. And once a cobra od regularly in a place, it is sure me a regular visitor; and no other will normally visit the place of the smell (specific species f the cobra. This may have given the belief of 'resident' cobras ct as 'protectors'.

ake must turn its head after (for envenomation)

nake does not have to turn its the ejection of venom, which is a a reflex action. In the case of the viper (Russel's viper), during its poisonous teeth (fangs) get d deep in the victim's flesh. To the biting grip and take its fangs viper has to turn its head in an direction as the fangs are and are bigger in size than in oisonous snakes. In the cobra, it and the echis (saw-scaled the fangs are smaller and they ily inflict a bite without turning ads.

drink milk

do, but then, not because of cial liking. When a snake is kept vity without food and water for period and then is offered any e it water or milk, it will drink it. lief is probably perpetuated by harmers — they may be keeping kes in the baskets without proper water and then when the snake out for the show, the charmer people to offer it milk (especially Panchami day), and the hungry sty snake drinks the milk.

drink milk from cows'

's no truth in it. If a snake is upon by cattle, it will naturally ound their legs and bite. Bite seen near the udders may have ise to tales of snakes drinking m the udders.

bites can be cured by mantras

is no authentic proof yet. During t several years, we have watched try for such cures, but in vain. hey seem to succeed, the reason elsewhere; for one, there are on-poisonous snakes than poison- or another, in some cases, the injected by the poisonous snakes e of negligible quantity. And, e mantriks may be playing on the psychology, especially because ke bite makes the victim panicky vous. The mantrik makes out the ness of the case from the local s at the site of the bite and when no serious consequences, he hanting mantras. Combined with ient's faith, the mantras help to remove the fear and nervousness. In such cases, even if nothing is done, and if the patient keeps his wits, the small amount of venom (less than the lethal dose, of course) will get neutralised in the body.

Incidentally, the mongoose is *not* immune to snake venom. It is the animal's extreme alertness and agility that helps it to stay clear of the snake's fangs during an encounter. Also, in its agitated state, the mongoose's body hairs stand up perpendicular to the skin surface and this causes the snake's strike to miss the skin.

Snakes have strong smells

Snakes have scent glands in the cloacal region (near the tail) which emit strong or obnoxious smells specific to their species. This smell is used as a mating signal (hence the glandular secretion is more during the mating season).

There is also the mistaken belief that if one kills one snake of a pair, the mate will seek out the person and bite him. There is no scientific truth in this. As mentioned earlier, snakes do not have a memory for persons; if a snake is found in the vicinity of the area where another had been killed, it may be simply because it is the mating season and the snake is out looking for a mate.

Old cobras have hairs or moustaches

Periodically, snakes cast off the slough (or cast skin), either in one piece or in bits. It is quite likely that in some cases, these bits may remain attached to the body and if observed from a distance may look like hairs.

One snake charmer had brought a cobra with moustaches to the Haffkine Institute. The snake died later and had been preserved. On dissection, it was found that a tuft of hair was thrust into the snake's head behind the eyes after making a small hole. The author had pointed out to the charmer how he could have thrust the tuft of hairs behind the eyes: the charmer confessed that's exactly what he had done.

● ●

Encounter with snakes

The best way of killing a charging snake

Snakes are difficult to kill by vertical strokes of the stick because of their serpentine movements. While crawling, a snake keeps its head slightly above the ground (to protect its jaws, eyes, etc). So, if one has to knock down a snake, the best way is to lash with a thin long stick horizontally on the head.

Can one escape strangulation by the larger snakes or the python?

Snakes have elongated lungs (two-thirds of their body length) which enable them to exert pressure of the coils on the prey and thus strangulate it to death. By keeping one's wits about, one can easily puncture the body (that is, its lungs) of the snake with a pointed instrument and escape from the ordeal if one occurs.

How to escape from an attacking snake

If you come across a snake accidentally, and if you have no defence, you may escape by throwing any piece of cloth, shirt, coat, headwear, sari, etc over the snake's body. It gets entangled and gets confused and you will have enough time to run away or get prepared for the encounter.

How to minimise snake infestation

Snakes will go where there's food — mainly frogs and rodents. Rodents always run along the sides of buildings (rat 'runways'). Normally, our dwellings have bushes, creepers or hedge trees touching the walls. This affords good protection for the rodents. Hence, do not allow any vegetation to grow touching the walls. Keep the surroundings clean; clear away accumulations of old building material, logs of wood, cast-away material, dumps, etc which provide the ideal hiding places for rats and reptiles.

It is also a common belief that snakes, especially cobras, prefer to live near sandalwood trees (or other such fragrant plants). But this is not due to the pleasant smell. The sandalwood trees provide moisture, coolness and shade which the cobras prefer.

N. E. VAD

Dr. Vad (52), whose main field of research, including his Ph D thesis, is poisonous snakes, was till recently with the Haffkine Institute before setting up his own snake farm at Ambarnath, near Bombay.

Those strange beliefs . . .

In Rajasthan, it was reported recently that the Peevana snake "sucks your breath away", a good story and a simple country way of describing respiratory paralysis from a nocturnal krait or cobra bite. Other venom fables include the one that a krait bite gives the victim as many bands as the krait had and that the mere lick of the (absolutely harmless) sand boa gives you leprosy. With all these stories being handed around, often within earshot of snake bite victims, it is no wonder that patients sometimes develop serious 'phantom' symptoms even with non-venomous bites. Shock is an important complication in snake bite and one of the first-aid measures is to calm the victim and treat the shock.

A leper recently showed up carrying a large cobra with a careful grip on the neck. The group of men with him had convinced him that a snake wouldn't bite a leper. It is unlikely that snakes are discriminatory when they bite.

ROMULUS WHITAKER

The giant black scorpion

COURTESY: ROMULUS WHITAKER

some stinging insects

S. S. JADHAV

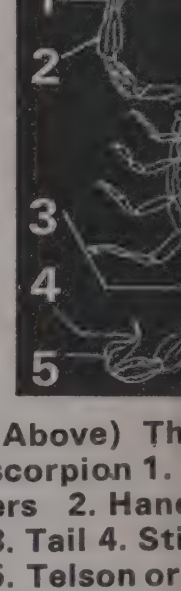
Scorpions are mainly found in warm and rather arid regions, between 50° latitudes north and south. The smallest adult may measure approximately 2 to 3 cm, and the largest between 15 and 25 cm. Scorpions are divided into three families—Buthidae, Scorpionidae and Vejovidae; the most venomous species belong to the Buthidae family.

Though official statistics are not available, private practitioners in Ratnagiri district in Maharashtra alone report four to five deaths per month from scorpion stings; the scorpion responsible is *Buthus tamulus* or the red scorpion. It is found all over India. Quite a few fatalities have also been reported from Bastar district in Madhya Pradesh and parts of Karnataka. The toxicity of scorpion venom varies from species to species, and also within the same species depending on the geographical distribution.

Scorpion stings almost always occur under accidental circumstances, more often at night. They occur in houses, in tents, in palmeries or in gardens. Though the number of stings is not perceptibly higher in children than in adults, the consequences are much graver (see box) in children. The parts of the body most frequently stung are the limbs or sometimes the head and neck of sleeping persons. The latter is more frequent in the case of infants and children.

The symptoms are mainly neurotoxic, and the reactions to stings of different species are very similar. The first symptom, immediately after the sting, is a sharp pain. This is follov by numbness or drowsiness and itching sensation in the nose, mo and throat. Abundant salivation a tears are observed. Muscle tone creases and sometimes muscle c tractures occur, affecting the lim the abdominal muscles or the phary Very young children often have c vulsions. Priapism (excitation of t sexual organ) is frequent. Muscle a eye reflexes are affected.

Acute suffering occurs as t symptoms develop. Salivation a perspiration greatly increase. Te appear, pupils get dilated and visi is impaired. The pulse rate increas going progressively out of rhyth Blood pressure rises at first, but fa later. There can be either hypo- hypertension. Some victims snee spasmodically. Body temperature is unstable, sometimes lower than normal. A fall in temperature is always a sign of aggravation. Respiratory movements are irregular. Death may occur due to respiratory paralysis.



(Above) Th scorpion 1. ers 2. Han 3. Tail 4. Sti 5. Telson or om gland. (Sting and te of black sc

Vomiting is the first sign that the toxin has attacked the nerve centres; the vomit may contain blood. Intestinal movements get exaggerated, and, at times, result in diarrhoea and melena (simultaneous excretion of urine and faeces). The may be excessive pain in urinatin involuntary urination and blood the urine may also occur. A typic symptom is increased sugar conte

THE CHILD KILLERS

Fatalities from scorpion stings in adults are rare in India, but many rural hospitals report several deaths annually in children. The adult victim will often be in severe " groaning pain " for five to six hours.

The two most abundant species of scorpions in India are: the giant black scorpion (*Palamneus* sp) and the red scorpion (*Buthus* sp). The black scorpion lives in holes and grows to over 20 cm; though its venom is not particularly toxic, its large venom gland (see figure on p. 53) can deliver a painful amount of venom. The red scorpion lives under rocks and rubble, and a close relative, the palm scorpion, lives under tree barks; both have more toxic venom. That is why scorpion sting is almost an occupational hazard among gravel workers and toddy-tappers.

Death is usually due to peripheral circulatory failure. In the absence of any other treatment, if the patient feels cold to the touch, blankets and vigorous massage of arms and legs can be life-saving. There have been cases where the victim has been revived after rubbing and massaging for nearly two hours.

There are no antivenins prepared in India for scorpion sting. Most doctors rely on pain-killers, and, if necessary, on stimulants, anti-histamines and blood pressure elevators to treat serious cases. There are hundreds of home remedies; most of them nicely serve to partially distract the patient from the pain and anxiety the venom causes. A simple remedy for an average scorpion sting is soaking the bitten part in ice and ammonia water for half an hour and an analgesic. If the sting is serious or a child is stung, a doctor should be seen immediately.

As far as is known, there are no other dangerous arthropods in India. With the notable exception of attacks by masses of bees, there seems to be no centipede, spider, ant, wasp or hornet which causes anything more than a painful swelling. However, for people who are hyper-allergic, even a simple bee sting can cause quick death (see SCIENCE TODAY, June 1974, p. 50). The tunnel spiders in the Western Ghats grow to tarantula size (tarantulas are a class of spiders; the Amazonian tarantulas measure about 7 cm in body length and 25 cm in leg span), but are apparently only mildly venomous. In the Andamans, the centipedes grow to over 25 cm in length and have a painful, but not dangerous, bite. The best first-aid for a painful insect bite is the quick application of a handful of wet mud.

But it is possible that someone develops a serious rash and goes to the local " doctor ". The patient is told that a year ago such and such a spider bit him, and now he is suffering from it; the remedy will cost him Rs. 5 only. According to toxicologists, such delayed reactions are unlikely and various food allergies are a much more common source of rash, hives, etc than insect bites.

ROMULUS WHITAKER

he blood. The level of sodium in plasma drops, while that of assium increases.

t has been established that the symptoms, other than local pain, ear from five minutes to 24 hours r the sting; in the majority of s, it is between 20 minutes and r hours. Death may occur as early several minutes after the sting or ate as 30 hours but, on an average, ween two and 20 hours.

An important characteristic of scorn sting poisoning is the sudden ravation of the condition of the im after the disappearance of the ptoms and apparent recovery. s is marked by sudden reappeare of grave respiratory trouble. erefore, the victims must be closely tched for at least 12 hours after the

COURTESY: ROMULUS WHITAKER

nptoms disappear totally.

How the scorpion venom acts is not fully understood. Local effects h as intense pain, inflammation and tering of eyes can be attributed to presence of histamine or 5-hydroxyptamine-like substances in the vem. The neurotoxin causes anxiety the victim, which leads to convulns. (The neurotoxic effects of the nom have been attributed either to central action on the medulla, nal cord and sympathetic prenglionic neurons or to a peripheral mulation of the post-ganglionic dings of the autonomic system.) orpion venom also affects neuroscular transmission.

Studies on venoms from scorpions widely differing geographical origin dicate several common chemical operties. The venom is a mixture of veral basic proteins; the enzyme ntent is usually low. Some species oduce two or more neurotoxins th similar pharmacological prorties.

Specific treatment ainst scorpion sting is the administration of scorpion antivenom. Anti-

scorpion serum was first produced in Cairo in 1909. Scorpion venom is a poor antigen. Immunisation of a horse for serum preparation, therefore, requires at least eight months and involves the use of 400 to 500 telsons (venom glands, or 400 to 500 scorpions). Yet, immunisation is never complete and certain physiological reactions to the venom are never suppressed even in horses immunised for several years. Antiscorpion serum was made in India on an experimental basis in 1961, but was given up later; the serum is expensive, costing Rs. 50 to Rs. 60 per injection, and besides, it is not very effective unless given early after the sting, ideally within 20 minutes. The amount of antivenin to be injected is very large, approximately 60 to 80 ml intramuscularly, even in infants.

As general treatment, a tourniquet may be applied soon after the sting a little above the sting; a light incision may be made to suck the venom out. This can be accompanied by the use of ice at the site of the wound; this will reduce the absorption of the venom and its diffusion in the body. Cauterisation (searing) for the destruction of venom in the vicinity of the sting and the use of potassium permanganate, hypochlorites, ammonia or phenol are useless. (But some of these may serve well as placebos as anxiety is one of the main symptoms, see box on p. 52.) Injection of large volumes of saline (200 to 400 ml) may be helpful because the solution dilutes the venom transported by the blood and counterbalances sodium eliminations from the plasma. Glucose solution should not be employed as it adds to the already increased sugar content in the blood. The use of atropine-ergotamine combination is also recommended. It has partial therapeutic use. Atropine helps to reduce the excessive intestinal secretions caused by the venom, while emetine, by inducing vomiting, helps clear the secretions. Corticoides may be used — they will help retain sodium and eliminate excess potassium in the plasma. Artificial respiration can be of help when respiratory paralysis seems probable.

Fanatic belief prevails in India in myths about the efficacy of religious rituals or certain types of soil or leaves of certain plants in treating scorpion stings. Among such remedies, not a single one has so far been found to neutralise the lethal effect of the venom in experimental animals.

Mr. Jadhav (27) is senior scientific officer at the Haffkine Institute, Bombay. He is doing his Ph D in pharmacology.

THE DEADLY MIDGETS

Spiders can be dangerously venomous, though there are no dangerous species in India. The Australian funnel-web spider (*Atrax robustus*, above), the South American species, *Phoneutria fera* (below), the American black widow (*Lactrodectus mactans*) and the brown widow (*L.geometricus*) spiders are among the most venomous. As with scorpion stings, children are particularly susceptible. There is a report of a single *Phoneutria* spider causing deaths of two children sharing a bed in a village in Sao Paulo, Brazil, on the same night.

Several human deaths have been reported from *Lactrodectus* spiders. Often they live in large clusters, and have caused virulent "lactrodectism" epidemics in Spain in 1833 and 1841, in Sardinia in 1833 and 1839, and in Texas in 1963.

Till recently, scorpion venom was collected by killing the scorpions, removing the stings and grinding them. The modern method is to administer an electrical shock. The scorpion is held by the forceps and kept under a glass petri dish with its tail out. When electrically stimulated, the scorpion squirts out its venom in a fine jet

From Alchemy to to-day's Science

Alchemy began by an obsessive urge for transforming the baser metals into gold. The alchemists never succeeded in making gold from base metals, yet their experiments recorded under mystic terminology, gradually led to the discovery of metallic arsenic, antimony and phosphorus.

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SARABHAI M. CHEMICALS

New bullock cart design

Of all modes of transport, India invests the maximum amount in bullock carts — Rs. 4,000 crores, including the cost of animals. Bullock cart is still the most important transport suited to the 'kutchha' rural roads; it costs less per tonne-km than any powered vehicle. And in recent years, bullock carts have been carrying 100 million tonnes of goods annually, which puts them only next to the railways.

The bullock cart is also most economical. Considering that the capital investment is about Rs. 1,000 to Rs. 1,500, with a low recurring operational and maintenance cost, and that the cart lasts nearly 30 to 40 years, the investment works out to be only Rs. 30 to 50 per annum. Despite its key role, it was only recently that the bullock cart came into focus for improvement. There are several problems with the present designs — the painfully heavy loads on the bullock's neck (often causing cancer), the high tractive effort due to the friction between the axle-shaft and the wheel-hub, the use of excessive materials for the construction of the cart and the effect of steel tyres on paved roads. There have been some new designs, but some of them take cart manufacturing out of the rural sector, throwing rural artisans and craftsmen out of jobs.

A major consideration in a new design worked out at the National Institute of Design, Ahmedabad, is to retain cart manufacturing in the rural areas. Besides increasing the employment potential, it stimulates the growth of rural industries. The design also attempts to introduce alternative ways of using materials and simple equipment.

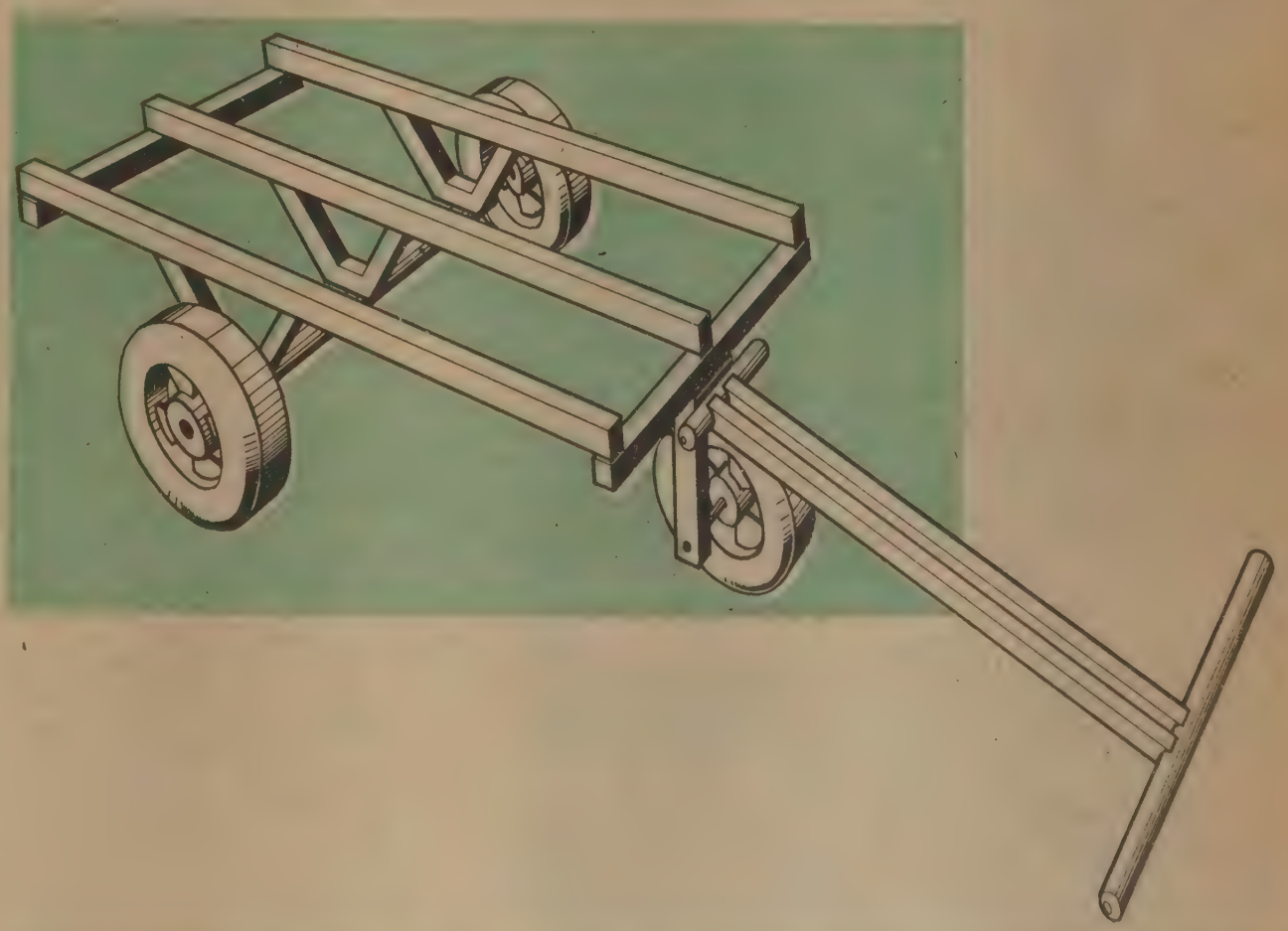
The new cart has three comparatively small wheels; the animals are not burdened with the entire load, but only required to pull the cart. The two rear wheels are pneumatic, while the front wheel is solid. They have 41-cm (16 inches) rims which can accommodate the new improved tyres available in the market, when the cart owner can afford it. Meanwhile, they can use old tyres and tubes of light trucks, which cost not more than Rs. 40 to Rs. 50 each. The steel rim can be fabricated in the village itself by simple manual process. The hubs and spokes are of wood. The existing hubs can be used as they are, or can be turned smaller. Similarly, the spokes can also be made from old wooden wheels. The steel rim is fitted over the spokes. The hub has two conical roller bearings to minimise friction.

The axle beam is a steel pipe fitted with wooden cylinders at both ends. The cart frame consists of three longitudinal wooden beams bolted to the axle beam. The front wheel acts as a guiding wheel. It has wooden spokes and fabricated steel rim, over which a solid rubber tyre is fixed. This can be easily made from an old rubber tyre by cutting off the side walls.

The yoke beam is attached to the front wheel. The yoke beam and the draw bar together are free to move in three planes, reducing the load and injurious effects on the bullocks considerably: (*i*) the pitching plane — to compensate longitudinal dislocations of the cart body and to prevent the yoke from jumping on the animal's neck; (*ii*) the rolling plane — to overcome lateral disturbances of the carriage, compensate for the varying heights of the animals, differing motions of the animals or lateral displacement of the cart owing to different ground levels; and (*iii*) the yawing plane — to enable easy turning and good manoeuvrability.

The comfort of the bullocks has a direct bearing on the overall efficiency of the bullock cart system. To avoid injury to the neck of the bullock, the new design has simple leather saddles. The other problem is damage to the hoofs on rough grounds. The traditional solution is to nail metal shoes on to the hoofs. But observations revealed that the metal shoes slip on paved roads and are dangerous on wet roads. To avoid this, rubber pads from pieces of old rubber tyre are fixed to the hoof. The total cost of the new bullock cart would not exceed that of the existing one.

S. BALARAM



Vacor: the super ratkiller

A remarkable single-dose rodenticide, developed by an American firm, kills rats that are resistant to even anti-coagulant poisons like warfarin. Called Vacor Ratkiller, this broad-spectrum rodenticide is equally effective against grown rats, black rats and mice, and most rodents die within eight hours of nibbling a few grams of the mash bait. Death is claimed to be painless because of the way the new compound functions, and it is also 'target specific' in that, while it is highly effective against rodents, it is relatively harmless when ingested by other animals or birds.

Rats are voracious eaters. They consume an estimated 33 million tonnes of food every year and eat up or spoil 20 per cent of the crops, even before the harvest. Since their incisor teeth grow at the rate of 13-15 cm a year, they must grind them

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wn constantly by gnawing whatr comes their way: boards, bricks, ncrete, lead pipes, electric wiring, d so on. Obviously, rats are the rld's most destructive creatures. d they are also known to be carrs of such diseases as plague, amoe- dysentery, rabies, jaundices, typs, tuberculosis, and rat-bite fever.

The extensive use of warfarin and ner slow-acting anticoagulant ronticides in the past few years has l to the emergence of the 'super-t' with a genetic resistance to ese poisons. Since 95 per cent of day's rat poisons are based on ticoagulants, the resistant rats have en multiplying unhampered, result-g in a rat population explosion of ch dimensions that the World ealth Organisation has called it n international menace'.

The Vacor Ratkiller was deve-ped over four years ago, but received full label clearance from e US Environmental Protection gency only recently. The lengthy d elaborate series of tests that the new product had to undergo included target specificity, palatability, effectiveness under use conditions, and secondary hazards for predator animals. These tests conclusively demonstrated its potency against all kinds of rats, including species resistant to warfarin.

The palatability of Vacor, evolved from a series of carbamate compounds, is said to be exceptionally good. This was demonstrated in paired preference tests, in which the rats were given complete freedom to choose between an unpoisoned ration and the same food containing lethal amounts of Vacor: they ate the latter without hesitation.

The new compound is a slow-acting, but acute, poison, which is desirable for an effective rodenticide. Since the rat dies several hours after eating only a few grams of the poison bait, it has enough time to return to its burrow before dying; and so, no carcass remains in the poisoned area to 'turn off' the other rodents.

BADIUDDIN KHAN

Fly ash to reclaim mined coal field

Surface coal mining leaves large tracts of land waste after mining. There have been several approaches and attempts to reclaim such land. The main problem is to neutralise the acidity in the mined soil. The US Bureau of Mines, in collaboration with a private firm, now proposes to test the commercial feasibility of using fly ash, waste material from coal-burning power plants, to neutralise the soil. The land will then be reclaimed, growing grasses and legumes on it. About 250 tonnes of fly ash may be used on an area of 0·4 hectare. To compare the feasibility, another 1·5-hectare land will be reclaimed using 50 tonnes of fly ash, fertiliser and lime.

K.P.N.

ndigenous cell separator fabric will boost attery technology

Nickel cadmium alkaline cells find extensive use in a number of devices — high-power radio mmunication sets, high-velocity ins and missiles, radar equipent, telephone exchanges, domestic dio receivers, flash guns, tape-corders, portable electronic calulators, miners' lamps, etc.

In these cells, a separator material placed between two electrodes. This aterial must be highly porous to ffer the lowest possible impedance the diffusion of gaseous oxygen. et the material must resist the formaon of active material bridges from ne cadmium electrode to the nickel ectrode and also resist penetration y particles of active material or ose wire ends from the nickel reen. It must be thin, highly absorent and should absorb five to seven mes its own weight of strong caustic otash solution (20 to 30 per cent) sed in the cell. Besides, it must be ble to resist attack by this solution. fter absorption, it must have minial electrical resistance and must be hysically strong to facilitate cell ssembly.

Originally, a very open porous elted cellulosic material was used or this separator. A typical material onsisted of 35 per cent Vinyon polyvinyl chloride fibre) and 65 per cent cellulosic fibre. Though the material had very high absorbency and porosity, and an acceptable mechanical strength, it lacked adequate resistance to attack by caustic potash and oxygen. Therefore, non-woven nylon materials were used later. Felted nylons have good electrical performance and physical characteristics, acceptable absorbency and resistance to caustic potash.

A large quantity of this nylon battery separator material (for about one million cells) is now being imported into India at an estimated annual cost of Rs. 1 crore. A synthetic-fibre manufacturing firm in Rajasthan has, in collaboration with the Electronics and Radar Development Establishment (LRDE), Bangalore, developed an indigenous nylon battery separator fabric. The fabric, 0·3-cm thick, has thousands of tiny pores, 200 per square cm, obtained by a special weaving technique. This plain weave (see SCIENCE TODAY, April 1977, p. 25) fabric with special denting arrangement (to produce a predetermined number of pores) has a strength of above 50 kg in both warp and weft direction. It absorbs 250 per cent of its weight of caustic potash solution (about 27 per cent) in 30 minutes, and shrinks only 1·5 per cent in this solution at 70°C. The solution has no chemical action on the fabric even on continuous exposure for 28 days at 27°C, and for 30 minutes at the boil. The manufacturers claim that the separation cloth performs excellently for over 500 cycles of charging and discharging and over 250 cycles under high rate of discharge conditions. Under normal conditions, the fabric can be stored for about five years.

The indigenous material compares well with the imported nylon fabric. Both have practically the same breaking strength (12·47 g for the domestic product against 12·35 g for the imported one). This increases to 12·34 g and 12·77 g, respectively, on treating with 27 per cent caustic potash solution at 70°C for 28 hours.

With the manufacture of this battery separator fabric in India, the nickel cadmium battery technology, now well established here, will receive a big boost. It will also clear the way for the production of rugged and high-performance batteries.

V. A. SHENAI

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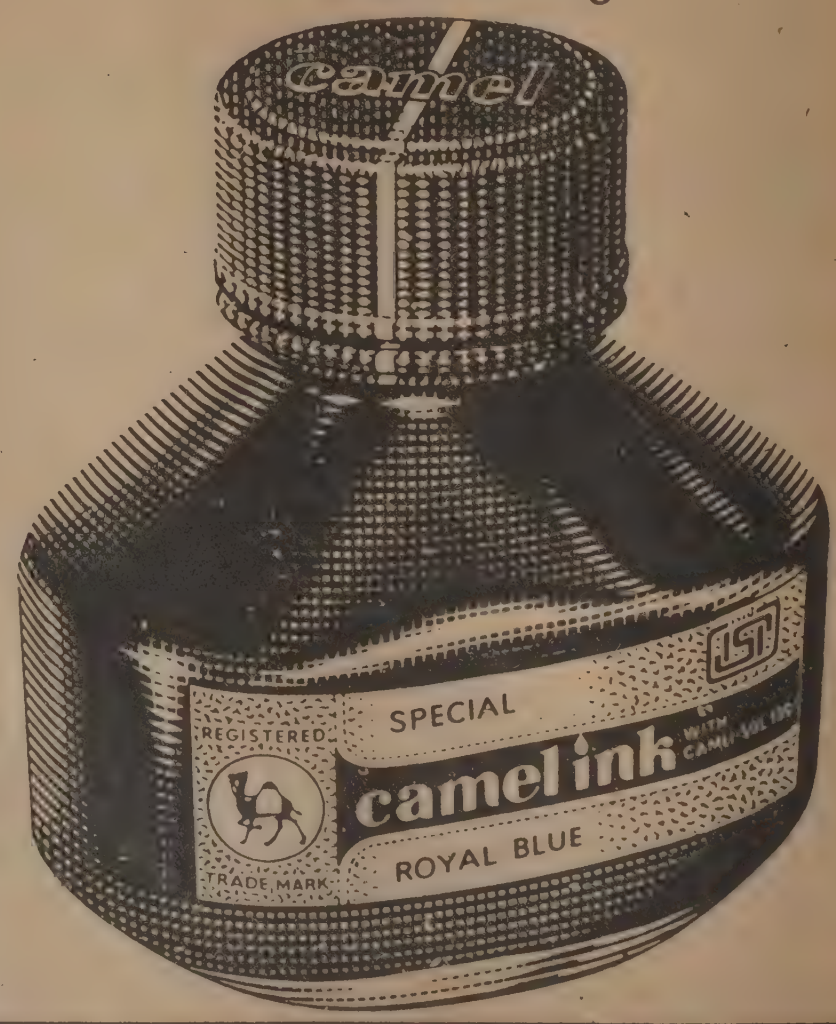

VISION 775

Nuclear options and diplomacy

INDIA'S NUCLEAR OPTION : ATOMIC DIPLOMACY AND DECISION-MAKING by Ashok Kapur, Praeger Publishers, New York, 1976, xx+ 295 pp, price not mentioned

It is surprising that the nuclear debate in India should have died out after the peaceful nuclear explosion (PNE) on 18 May 1974. The event propelled India into a paradoxical situation. The explosion was described as being for peaceful purposes. India's position, therefore, lay between the nuclear weapons powers and the non-nuclear states. Many responses of the nuclear weapons powers, like the efforts to control the spread of nuclear technology, are directly related to India's PNE. The lack of debate, therefore, is difficult to comprehend. Perhaps the pro-bomb lobby is satisfied, and the anti-bomb section is disheartened.

Ashok Kapur's book should, hopefully, stimulate greater awareness of India's further options and responsibilities. He proceeds on the assumption that security considerations have shaped India's nuclear policy. Being a "power in the middle", nonalignment suited India's desire to engage in power politics through diplomatic means, while neutralising the capability of the United States, the Soviet Union and China to influence sub-continental polity. He asserts that Nehru was aware of the Chinese threat even before 1954, and this influenced his policy of deliberate ambiguity on the nuclear question. Whereas nuclear weapons were decried, the peaceful uses of nuclear energy were stressed. At the same time, international safeguards were resisted. A speech by V. C. Trivedi, leader of the Indian delegation at the Geneva Disarmament Conference, in August 1965, is quoted: "Institution of international controls on peaceful reactors and power stations is like an attempt to maintain law and order in a society by placing all its law-abiding citizens in custody while leaving its law-breaking elements to roam the streets."

India's position on disarmament changed radically around 1964–1965. China exploded her atomic bomb in October 1964. Besides, discussions on the non-proliferation treaty started at this time. India linked the question of horizontal proliferation with reduction of existing arsenals, and sought credible guarantees for all non-nuclear weapons states against threats from nuclear powers. Simultaneously she made a distinction between nuclear weapons and nuclear explosives technology for peaceful purposes. In fact, the contradiction in postures was necessary for the growth of India's nuclear policy: "India believed in national peaceful atomic technology proliferation. But, on the other hand, India took the categorical view that it continue to decide against nuclear weapons." India's option was, thereby, kept open.

Kapur has not highlighted sufficiently the technological aspect here. By 1964, India had both a nuclear reactor and a plutonium reprocessing plant within national control. This permitted a nuclear device to be exploded around 1966, had a decision been taken after the conflict with China. An interesting point made by the author is that a decision was, in fact, taken by Shastri in December 1965 acceding to Bhabha's request for a subterranean nuclear explosion project. The story leaked; however, nothing came of the idea due to the deaths of both Shastri and Bhabha in January 1966. In the absence of archival material, this assertion must be treated with reservation.

Some perceptive observations are made about the elitist character of atomic decision-making. Societal pressure was in favour of all steps that kept the option alive, like not signing the Non-Proliferation Treaty (NPT). The Cabinet was generally in favour of an independent nuclear policy. It is doubtful if debates in Parliament or in academic circles influenced the decision-making apparatus in any meaningful manner which centred around the Ministry of External Affairs, the Department of Atomic Energy and the Prime Minister's Secretariat. Personal equations were all-important here and revolved around the relationships between Nehru and Bhabha initially, then Shastri, Bhabha and L. K. Jha and, finally, Indira Gandhi and Sarabhai and Sethna. In the Indian situation, however, the influence of the Prime Minister was predominant. Certainly, the decision to conduct the PNE in 1974 could not have been made by anyone except the Prime Minister, and it is doubtful if the Cabinet was even consulted.

Which brings us to the question as to why the PNE was felt necessary. Kapur offers four explanations: that it was a political act, that it was a response to the oil crisis, that it was intended to demonstrate India's relevance to the superpowers and that it signalled India's protest against the order sought through the NPT regime. Strangely enough, he neglects security and domestic political imperatives. Statements after the PNE made clear that a decision in this regard was taken around September 1971. Given the prevailing security environment in 1971, the PNE must be deemed to have a security rationale. Further decisions would have been taken sometime in late 1973 when site preparation was started and again in early 1974, when the test was to be made. These decisions were most probably motivated by the need to boost the national morale with the economy staggering under the impact of bad harvests, industrial unrest and raging inflation.

What were the international effects of India's PNE? Beyond verbal declamations, the Western powers, notably, began propagating fears of a proliferating world. The main challenge, Kapur believes, was to the NPT regime and the many anomalies in the Treaty, particularly the unequal responsibilities of nuclear weapons powers and non-nuclear weapons states. A case is made out for modifications essential for the applicability of that Treaty.

One must agree with Kapur that the PNE does not indicate that India has embarked on a weapons programme — that would require further decisions and financial outlays. What the PNE has achieved is "to stretch out the option and make it internationally visible by demonstrating independent capacity". A problem arises: for how long can the option be stretched out? Surely the law of diminishing (political?) returns must set in.

A host of other relevant issues have been dealt with like threats to the nuclear order by threshold powers, Indo-Canadian nuclear co-operation, compulsions to export nuclear technology by the scientifically capable powers, the Pakistani proposal for a nuclear-free zone in South Asia, and the significance of China in India's nuclear policies. The book will interest laymen; for the student of nuclear politics, it would be invaluable.

P. R. CHARI

[Mr. Chari is Director of The Institute for Defence Studies and Analyses, New Delhi.]

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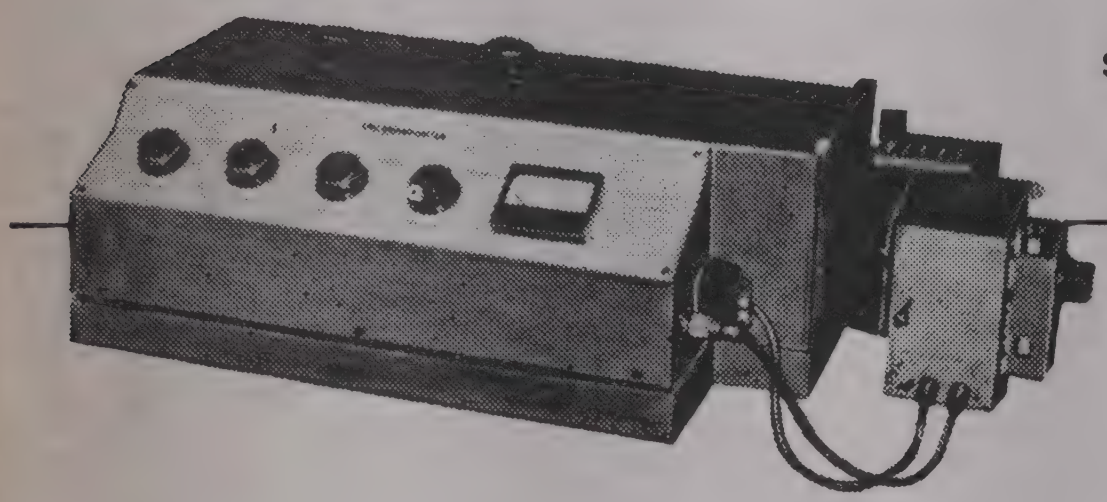

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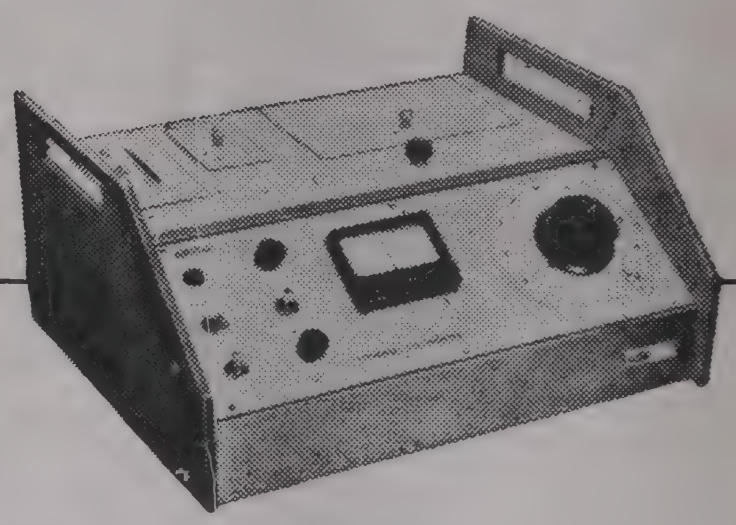

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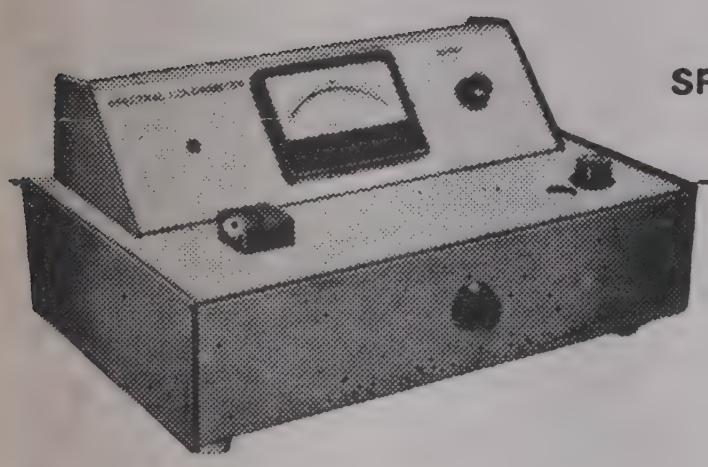

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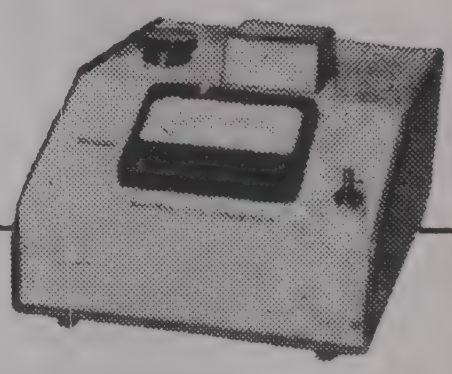

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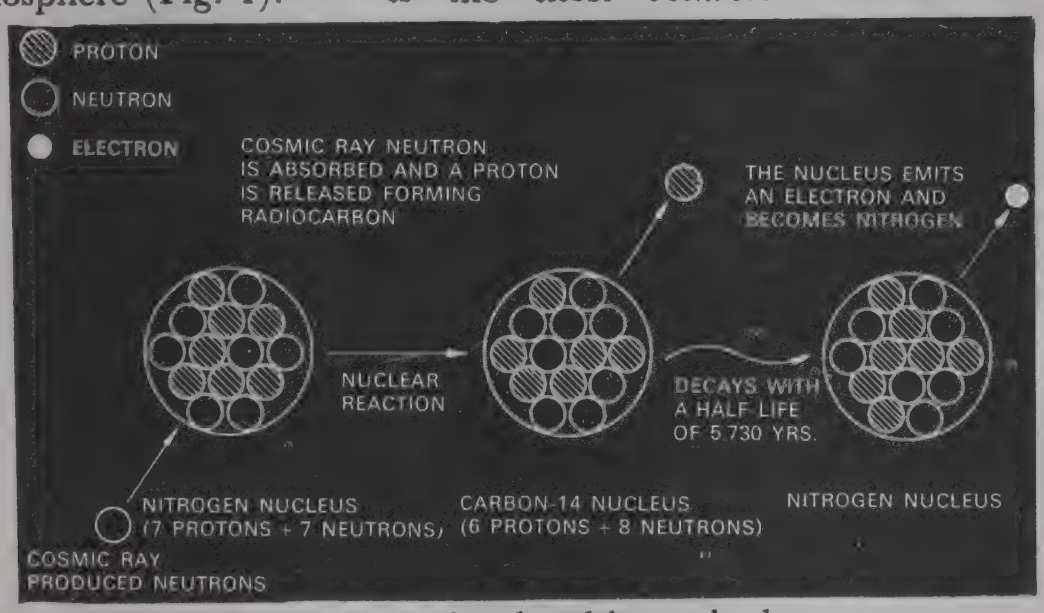
hat is radiocarbon clock? Is it accurate?

he radiocarbon method is now widely used for dating archaeological samples. The me- was discovered by Willard by for which he was awarded the el Prize in 1960. Archaeologists world over rejoiced at the epoch- ing discovery, since the method vided them with a powerful tool. v does the method work?

arbon-14 is an isotope of carbon. topes of an element have the e number of protons in their lei, but different numbers of trons. They are chemically in- nguishable. Thus, chemically, ^{14}C dentical to the common isotope .) It is produced when slow trons present in cosmic rays enter- the Earth's atmosphere from er space interact with the nitrogen ns of the atmosphere (Fig. 1).


PROTON
NEUTRON
ELECTRON
COSMIC RAY NEUTRON IS ABSORBED AND A PROTON IS RELEASED FORMING RADIOCARBON
THE NUCLEUS EMITS AN ELECTRON AND BECOMES NITROGEN
NUCLEAR REACTION
DECAYS WITH A HALF LIFE OF 5,730 YRS.
NITROGEN NUCLEUS (7 PROTONS + 7 NEUTRONS)
CARBON-14 NUCLEUS (6 PROTONS + 8 NEUTRONS)
NITROGEN NUCLEUS
COSMIC RAY PRODUCED NEUTRONS

smic-ray pro- ed neutron is orbed by a ogen nucleus form radioac- carbon (^{14}C). carbon-14 nu- s decays with lf-life of 5,730 rs to a nitrogen leus

The ^{14}C is radioactive and like any er radioactive species it decays the time. The rate of decay is erned by its half-life (the time takes for any radioactive species decay into half of its original ount), which is taken as 5,730 rs.

Both ^{14}C and ^{12}C combine with gen in the atmosphere to produce bon dioxide ($^{14}CO_2$ and $^{12}CO_2$). e ratio $^{14}C/^{12}C$ in the atmosphere very small $\sim 1 \cdot 3 \times 10^{-12}$. Plants otosynthesise their food with the p of chlorophyll and light, using bon dioxide. The ratio $^{14}C/^{12}C$, wever, remains largely the same ether the carbon is in plants or nsumed by animals or humans.

Since plants and animals consume d, whatever ^{14}C decays is re- nished as long as the organism is ve. When it dies, ^{14}C continues to cay, but there is no replenishment ough food intake. As a result, C depletes with time, but ^{12}C being ble does not and the ratio (specific ivity) goes down with time. Thus, e older the sample, the less the cific activity (per gram of carbon).

Assuming that the intensity of cosmic rays (hence, the production of ^{14}C) has not changed with time, a living organism at any time in the past must have had the ratio $^{14}C/^{12}C \sim 1 \cdot 3 \times 10^{-12}$. Hence, if one can find out how much ^{14}C is left in the organic remains, one can, using the known rate of decay of ^{14}C, find out when the organism died. Thus, we have a dating method based on the measurement of radioactivity due to ^{14}C in organic remains. The method is, hence, known as radiocarbon dating or radiocarbon clock.

Materials of organic origin only can be dated by the method; one can't, for example, date rocks. Generally, the organic remains are in the form of bones, antlers, hair, charcoal, charred grain, wood, etc. Charcoal is the most reliable material for dating by this method.

The samples are initially processed to get rid of extraneous carbon which could be present in the form of rootlets, humus, soil carbonates, etc. They are then converted into a suitable gas (carbon dioxide, methane, acetylene, etc) through radiochemical processes to fill the gas proportional counter used to measure ^{14}C activity. In our laboratory, the samples are converted into methane. The measurement of ^{14}C activity requires quite sophisticated techniques, since the radioactivity is extremely weak.

One can date the remains of organisms that died up to some 45,000 years ago (7 half-lives of ^{14}C) by this method. All the radiocarbon dates are, however, accompanied by statistical errors, since radioactive decay is a random process governed by the laws of statistics. For a typical sample of about 4,000 years' age, one standard deviation (68 per cent probability) error is about $\pm$ 100 years.

In recent times, some doubts have been raised about the accuracy of the radiocarbon clock. The corrections suggested have come from an entirely unrelated branch, dendrochronology or the science of dating trees. Each year a ring is added to a tree trunk. If one cuts the stem of a tree horizontally, and counts the number of rings at the exposed end (see figure below), one can estimate the age of the tree. Sophisticated methods to count tree rings and determine the age have been developed. Thus, the dates of some of the sequioas and bristlecone pines that have lived for more than 5,000 years in the USA have been determined. But, when wood from such trees was dated by radiocarbon clock, it was observed that, as one went back in time, the radiocarbon dates came out progressively younger than the tree-ring dates. This led some scientists to suggest calibration curves to correct the radiocarbon dates. But, are these corrections valid or necessary?

An examination of well dated archaeological sites from West Asia and Egypt by the radiocarbon clock indicated that the corrected radiocarbon dates become too old to be archaeologically accepted. It is possible that something is wrong with the tree samples, since all of them have come from California hills, at altitudes of 3,000 m; these trees may have been subjected to some special effects. Such doubts have led some workers to build up tree ring chronologies on bog-buried oaks in UK and Ireland, which then can be independently dated and compared with the Californian trees. In summary, the available evidence seems to point that, perhaps, radiocarbon dates beyond 2000 BC require some correction; only further research will be able to determine the exact amount. Meanwhile, it will be wise to use uncorrected radiocarbon dates and say so explicitly.

D. P. AGRAWAL
SHEELA KUSUMGAR

[Dr. Agrawal and Dr. Kusumgar are with the Physical Research Laboratory, Ahmedabad.]

YOU TOO CAN DO IT

IC BABY ALARM

Loudspeakers are designed to convert electrical energy into sound energy. There is a magnet over which a coil, called voice coil, with a few turns of copper wire is wound. The coil can move axially along the magnet. The voice coil is attached to a paper cone. When an alternating current passes through the coil, it vibrates. These vibrations are passed to the cone which transmits them through air as sound waves.

If we reverse the process, ie, if we give some sound vibration to the cone, we can get the corresponding electrical impulses across the voice coil. Though this output from the loudspeaker is very low, it can still be used, after sufficient amplification, to act as a microphone. This is the principle used in this integrated circuit baby alarm. A loudspeaker situated in another room is utilised as a microphone. Except for the addition of the transformer T1, the amplifier circuit is almost identical with the integrated circuit amplifier published in SCIENCE TODAY, February 1977, p. 76.

The sound vibrations are sensed by the loudspeaker and converted by the loudspeaker into corresponding electrical signals. These signals are transmitted through the flexible wires to the transformer T1 at the input of the amplifier. The high step-up winding ratio of this transformer boosts the signal received and feeds the integrated circuit amplifier. The amplifier amplifies this signal and you hear the sound, loud and clear, from the second loudspeaker.

The output transformer T2 is readily available in the market. The transformer T1 is a special step-up transformer with a primary to secondary turns ratio of 1 : 30 to 1 : 50. You can get this transformer made to order from any transformer manufacturer or you can wind it yourself (details are given below). If the size of the transformer is not of much importance, then you can use the standard ready-made output transformer suitable for vacuum tube EL 84. While using this transformer, connect the normal low impedance, ie, low turns, secondary as primary, and vice versa.

To avoid the interference of the mains supply, use twisted flexible wires between the speaker used as a microphone and the amplifier unit; as far as possible, keep this wiring away from the mains wiring and connect the laminations or the brackets of the transformer to ground as shown in the diagram.

As the unit will be kept in operation for a long period, a 9 volt battery eliminator is recommended.

While testing, keep both the loudspeakers of the unit at least three metres apart to avoid the squealing sound due to feedback through air between the two speakers.

Construction of Transformer T1

Material Required: 1. enamelled copper wire, 43 SWG, 50 gm; 2. Core Type 17 CRGO grade 51, 100 gm; 3. Bakelite bobbin, type 17 square, $\frac{1}{2}'' \times \frac{1}{2}''$, 1 no.

Primary: 50 turns of 43 SWG enamelled copper wire.

Insulation: interwinding (between pri. and sec.) paper insulation.

Secondary: 1500 to 2500 turns of 43 SWG wire. Interlayer insulation not required.

You will need:

Integrated Circuit: CA 3020 or CA 3020A, 1 no.

Capacitors: electrolytic

250 mfd 12 V, 1 no., 10 mfd 12 V, 1 no., 5 mfd 12 V, 1 no., 1 mfd 12 V, 1 no.

Polyester or ceramic

0·22 mfd 1 no., 0·01 mfd 1 no.

Resistors (all half watt):

470 KΩ 1 no., 2. 2K Ω 1 no., 100 Oh
·1 no., 1 Ohm 1 no.

Volume control: 5 K logarithmic w
switch, 1 no.

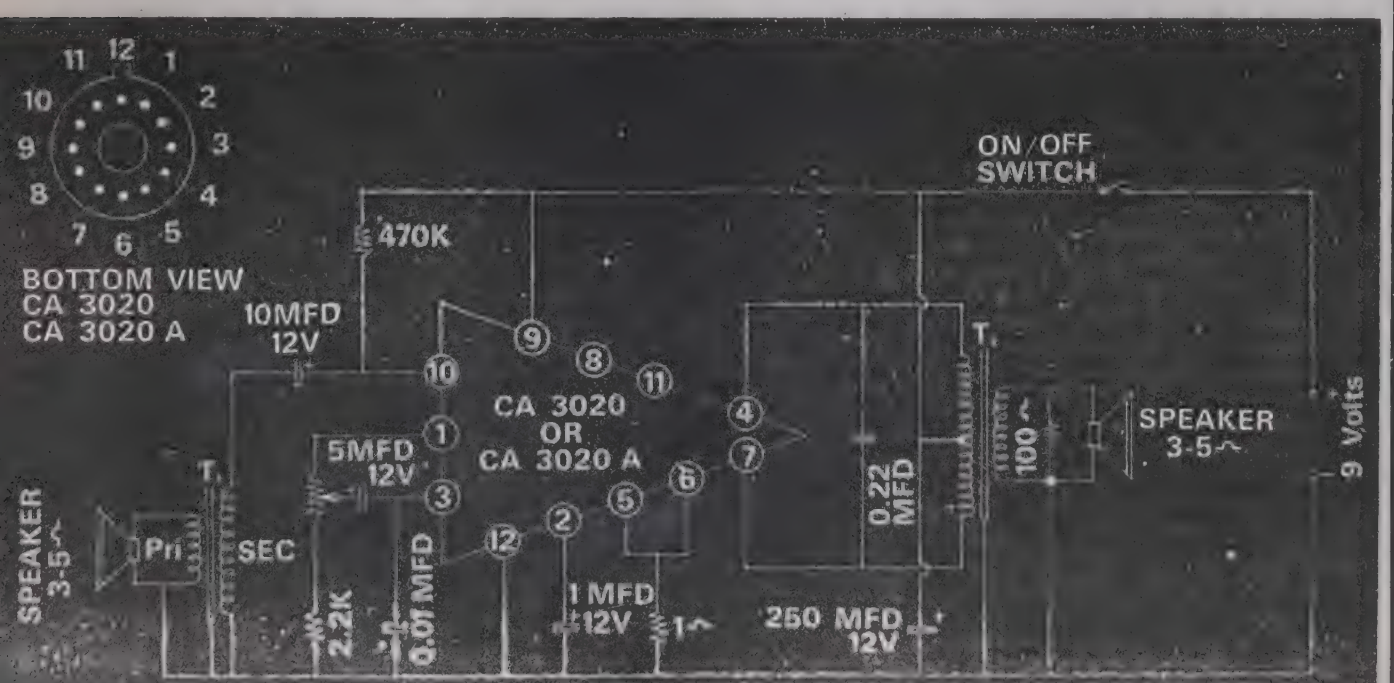
Transformers: for T1: See text for mate
and constructional details, or
Output transformer for EL 84 ie p
5K Ohms; sec: 3 to 5 Ohms 1 no.
for T2: Output transformer 500 m
pri: 100 to 180 Ohms sec: 3 to
Ohms, 1 no.

Loudspeakers: 500 mW, 3 to 5 Ohms, 2 n

Supply: 9 Volt battery eliminator

Misc: Screws, wires, solder, knob, su
able enclosure, etc.

ANIL V. BORKA



BRAIN TEASERS

OVERSIGHT : A book-seller went t buy some chemistry and mathematic books from a wholesaler. He bought 6 books in all and paid Rs. 1,250 for them On return, he noticed that the wholesale had charged him the price of a chemistr book for each mathematics book, an vice versa. The mistake resulted in a overpayment of Rs. 100. If the price difference (in rupees) between a mathe matics book and a chemistry book is th same as the difference in the numbers o books of the two subjects bought, wha was the price of each mathematics and chemistry book ?

B. L. ARORA

HOW MANY STUDENTS ? The product of the numbers of students studying in two divisions is 2,021. How many students are there in each division ?

V. A. SHENAI

(Solutions next month)

Solutions to last month's Brain Teasers

Movie and Dinner

Let m, d and t be the amounts spent on the movie tickets, dinner and taxi fare, respectively.

$$\text{Now } t = m + \frac{d}{2}$$

$$\text{but } m = 10$$

$$\text{So } t = 10 + \frac{d}{2}$$

$$\text{Also, } d = m + t$$

$$d = 10 + 10 + \frac{d}{2}$$

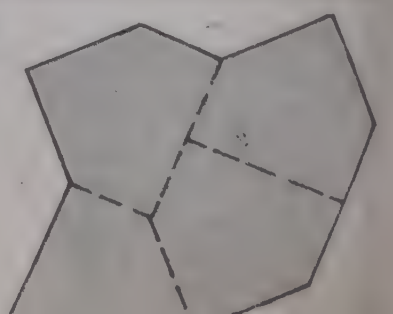
$$d = 40$$

$$t = 30$$

Thus, I had spent $m + d + t$ = Rs. 80.

Equal Division

Cut as shown



TELL US WHY...

. . we see bright spots of light when press upon our eyelids?

s everybody knows, we see objects because photons (light cles) reflected from these objects, entering the eye, stimulate etinal cells. These cells respond to the external stimulus and their signals via the optic nerve to the rear of the brain. e, in the 'visual area' of the brain, the signal is "intered", and the 'image' formed. Now, it is not necessary that external stimulus be restricted to photons. Any kind of ulus to this optical system of retina, optic nerve and visual ex may produce visual effects — usually in the form of ks of coloured light, sometimes appearing in complex metrical patterns. Such flashes and patterns are called sphenes.

ne of the simplest methods of producing phosphenes is to or a sufficiently long time in a totally dark room. In the nce of the normal background of external light stimuli, the cal nerve cells will begin to fire on their own (autoexcita— like the twitching of an inactive muscle) to produce a ant display of lights. This phenomenon has often been d by prisoners confined to dark cells. It may also be respon- for the visual illusions seen by mystics meditating in the , or with closed eyes.

ne latter possibility is strengthened by the fact that various s of nervous disorders are also known to produce phosnes. Individuals with migraine headaches sometimes 'see' nes on the side opposite to the aching half of the head.

ne retina may also be stimulated by *mechanical pressure*. nebody who claims to have seen stars on receiving a blow he head is not necessarily indulging in poetic licence. A tler technique, familiar to all children, is to close the eyes then press down on the eyelid. A single finger will produce, he opposite side of the eye, a solid dark circle surrounded bright halo and increasing the pressure will improve the rtainment.

Systematic research into the phenomenon of phosphenes goes back to the 18th century with the discoveries, by Benjamin Franklin and Allesandro Volta, that they could be induced by electrical impulses. In 1819 Johannes Purkinje discovered that by rapidly making and breaking an electric current between his forehead and tongue, he could produce persistent and stable phosphenic images. An essentially similar technique was used by Max Knoll in 1932. Knoll taped electrodes to his temples and passed low voltage (1 volt) periodic pulses through his brain. He found out that when the frequency of the pulses was in the range of his brain waves (5 — 40 cycles per second), the phosphenic effects were most pronounced.

The most promising results in the study of this area come from experiments in which the visual cortex is directly stimulated by electrodes. If the extreme rear of the visual area of the brain is electrically stimulated, specks of light are 'seen'. Moving the electrodes forward, to the area of 'visual association', will elicit geometrical patterns. Still further in front, electrode stimulation produces vivid images of past experiences.

In principle, it should be possible to reproduce vision in blind people by carefully mapping the visual cortex and appropriately placing an array of electrodes which would then be connected via a decoding computer to a photoelectric 'eye'. This has already been attempted by several teams at the Universities of Cambridge (England), Utah (USA) and Ontario (Canada). (See SCIENCE TODAY, March 1974, p. 10.)

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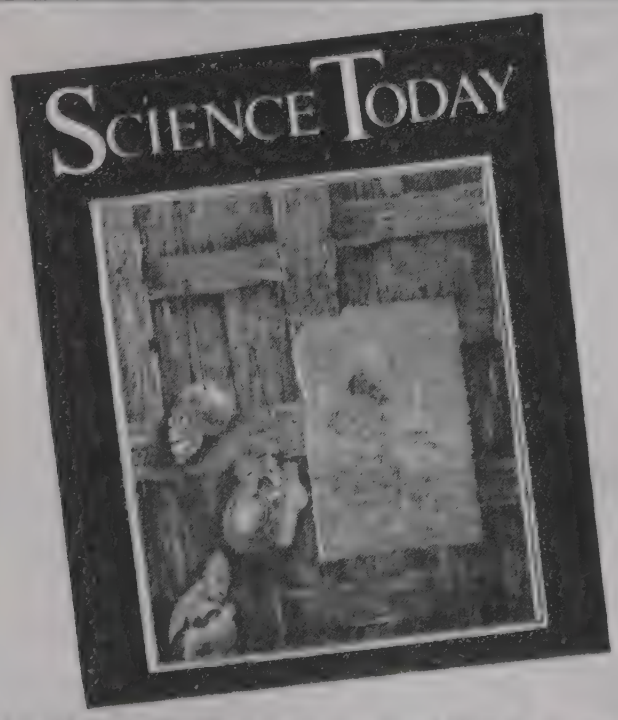

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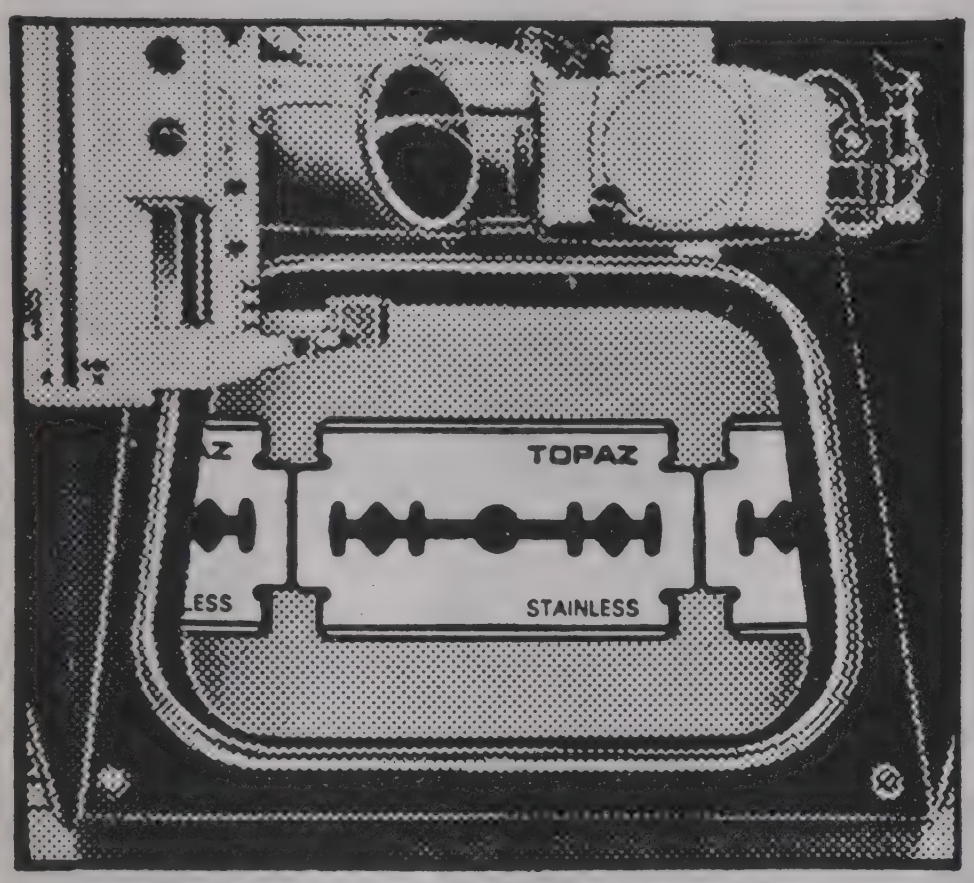

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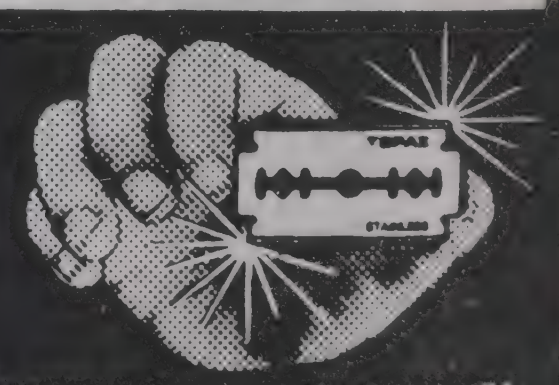

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Index to Volume XI July 1976 — June 1977

(Figures in italics denote issue numbers)

ɔn *4* 51-58; artificial abor-
ents *7* 7
n, N. *7* 49
c holography *11* 57-58
ıcture, for animals *2* 11;
ser *6* 11
4 15-24; in India *4* 25-27;
8 8; freedom of choice &
ge *10* 9
ion & diet *8* 15
S. S. *1* 31; *4* 49
cidents? what lies behind
40; *12* 6
, navigational aids *9* 28;
nd effects *9* 36
s, noise *2* 13; air traffic
ol in *9* 32
, & vision *9* 9; & birth
ts *11* 8
im *5* 36
n in animals *3* 27; *11* 10
ecycling of *9* 8
, S. R. *10* 35; *11* 29;

ation, pain after *4* 30
ɔn, Robertson S. *4* 35, 43;
6 25
ica, *1* 61; animals *2* 56
dies & tissue typing *12* 17
, Australia *6* 51
ɔmbat in *2* 29
nguage in *10* 36-44
ata I *1* 53-54
ata, neutron & gamma
tudies *8* 25
& cockroaches *11* 9; &
aglandins *9* 18
gy *2* 35
ɔmical, distances *2* 61;
es *6* 71; *8* 9
s, injuries to women *3* 13
ɔheric exploration *4* 13
& Appointments:
ndia Oil Technologists'
ciation medal *11* 61; Amrut
y award *10* 60; Andhra
esh Academy of Sciences
; B. C. Roy award *11* 61;
ience award *11* 61; Bor-
award *10* 60; Cancer
rch award *11* 61; Com-
wealth Bursary *8* 79; Com-
wealth Institute of Ento-
gy *6* 77; Computer Society
dia *4* 75; FIE Foundation
d *3* 75; FRS *10* 60; Hari
Ashram award *1* 71; *8* 79;
11 60; Hooker award *10* 60;
I head *9* 61; ICAR special
d *1* 71; ICMR award *2*
ICSU *4* 75; Independence
award *4* 75; Indian
lemy of Medical Physics
; Indian Chemical Society
60; Indian Institute of
nical Engineers *8* 79;
ɑn Psychiatric Society *10*
Indian Society for Tech-
Education *8* 79; INSA,
bers *5* 77; award *10* 60;
national Association of
hquake Engineers *8* 79;
n Society Fellowship *11*
Jawaharlal Nehru award
; *8* 79; Jawaharlal Nehru
wship *1* 71; Lady Tata
ɔrial Trust award *2* 69;
gmuir award *7* 79; Leon
ard award *1* 71; Metallur-
of the year *7* 79; Pharmacy
ɔil of India *2* 69; Pitam-
bar Pant award *8* 79; Public Health Engineers *10* 60; Republic Day award *9* 61; S. S. Bhatnagar award *10* 60; Subramanyam Achievement award *6* 77; Telecommunications award *3* 75; Torpedo study *10* 61; UGC fellowship *11* 61; (US) NAS *1* 71; USSR Academy of Sciences *1* 71; VASV Kendra award *8* 79; Verman award *7* 79; Vikram Sarabhai award *10* 60; Walter Puckey award *3* 75; Westinghouse award *11* 61; Yant Memorial award *7* 79; Young Scientists award *6* 77

Bacteria, resistant clothes *5* 15; antibiotic resistance *12* 9
Balaram, S. *6* 59; *11* 31; *12* 55
Balloons for research *5* 17-25
Bamboo as structural material *2* 13
Banerjea, H. N. *5* 45
Baobabs *11* 26; & continental drift *9* 41
Bathroom singing *9* 41; *11* 6
Battery cells *12* 57
Baxi, Arvind J. *6* 51
Beauty *5* 13
Bedekar, G. V. *4* 59
Bed-wetting, causes of *11* 10
Bees, electric communication *9* 8
Berwick, Stephen *6* 53
Bhabha, Homi *4* 35; *5* 47; *6* 24
Bhagat, S. A. *6* 35, 43
Bhambi, P. N. *5* 60, 63
Bhaskara II *3* 65
Bhatnagar, A. *8* 69
Bhattacharya, S. S. *12* 26, 35
Bhide, M. B. *12* 46, 50
Bhise, S. B. *12* 46, 50
Birds, our vanishing *2* 53; *3* 53
Bird watching, electronic *5* 15
Birth control *8* 11
Birth defects & alcohol *11* 8
Black box in aircraft *7* 74; *9* 30
Black hole?, how black is a *11* 13-20
Blood, & heights *1* 13
Blumberg, Baruch S. *6* 51
Body's chemicals *3* 11
Bone for dogs, artificial *9* 9
Books reviewed:
Asimov's Guide to Science, Vols. I & II *3* 57; *Concepts of Modern Mathematics* *5* 64; *Design-out Maintenance and Instrument Aids* *5* 64; *Discussion on Incompatibility in Flowering Plants* *2* 52; *Elements of Electronic Navigation* *6* 59; *Electricity and Magnetism* *10* 49; *Food Technology in 1980s* *1* 55; *From Voice Signals to Satellite Communication* *6* 59; *India in Space* *6* 61; *India's Nuclear Option* *12* 59; *India's Wildlife in 1958-70* *11* 50; *Mankind at the Turning Point* *4* 59; *Maths or Magic?* *9* 55; *Matrices and Tensors in Physics* *1* 55; *Mechanical and Industrial Measurements* *10* 48; *Modern Immunology* *6* 61; *Modern Physics*, *10* 49; *Optimisation Methods in Operations Research and Systems Analysis* *8* 65; *Penguin Book of the Natural World* *3* 57; *Penguin Book of the Physical World* *3* 57; *Process Equipment Design* *8* 66; *Status Study of Population Research in India* (Vol. III) *7* 73; *Survival 2001: Scenario from the Future* *7* 73; *Technology of Textile Processing* (Vol. I & Vol. V) *11* 50
Boranes, structure of *6* 48
Borkar, Anil V. *1* 68; *2* 67; *3* 73; *5* 77; *6* 75; *7* 77; *8* 77; *9* 59; *10* 59; *11* 59; *12* 62
Brain Teasers: *1* 65; *2* 67; *3* 73; *4* 73; *5* 73; *6* 75; *7* 79; *8* 77; *9* 57; *10* 59; *11* 59; *12* 62
Brahmagupta *2* 59
Brahmananda, P. R. *6* 52
Breast cancer *10* 8
Breast feeding *8* 52-59
Breeder reactors *1* 33-41
Bridges, why they collapse *6* 35-43; *8* 8; *9* 5; *10* 6
Bullock cart design *12* 55
Burt, Cyril & IQ fraud *6* 33
Buttons, instant *4* 11

Caffein & coffee intake *8* 26
Canals, Transbasin *2* 17-25; *5* 9
Cancer, & drinking water *5* 13; & fire retardants *9* 7; & Vitamin C *7* 12; and diet *7* 15; of the breast *10* 8; of the lung *8* 12; blood test for *6* 11; tracing *9* 9
CANDU reactors, thorium fuelled *4* 31
Cars, anti-drag grille *4* 12; saving fuel downhill *10* 47; *12* 6; gas bag jack *12* 8
Cassette, variable bias *11* 11
Cats and pregnant women *4* 11
Cement for rural housing *5* 43
Chhapgar, B. F. *12* 36, 42
Chari, P. R. *12* 59
Childbirth, effect of painless *8* 13
Children, IQ & progesterone *6* 12; & moving house *9* 8; & polluted air *11* 32-39
Chillies *7* 14; & cancer *9* 5
Chitnis, B. V. *5* 64
Chlorofluorocarbons *3* 12
Choudhury, Saroj Raj *7* 40; *11* 50
Cigarettes, & drug metabolism *3* 29; & heart attacks *11* 8; low risk *8* 29-35; *11* 6
Claustrophobia *6* 13
Cockroaches & asthma *11* 9
Coffee & caffeine *8* 26
Colah, J. J. *6* 46
Computer, is it intelligent? *2* 37-44; *5* 9; *7* 7; *10* 6; & movie magic *12* 9
Concorde's sonic bang *2* 32
Conservation of wildlife *5* 36-42; *6* 9, 53-58; *7* 38-45; *8* 7; in China *7* 41
Continental drift *1* 9; & baobabs *9* 41; & India *8* 11
Contraceptives: vaccine *4* 11; IUD pill *4* 11; fungal *8* 11; & infertility *12* 7
Cotton fabrics & finishing gimmicks *10* 25-30
Cow plasma to stop bleeding *7* 12
Cricket ball, aerodynamics of *3* 46-52
Crystals, liquid *12* 11-16; peering through *9* 8
Cyclones *2* 62; warning for fishermen *1* 45
Cylindro-spherometer *4* 45

Damle, P. G. *6* 61
Daniel, J. C. *6* 53
Dastur, Dinshaw J. *2* 17, 68
Dastur, Dorab K. *6* 51
Deaf, teaching speech *8* 13
Deer, painless musking *1* 7
Deshingker, A. V. *4* 67, 70; *5* 65; *6* 66; *7* 68; *8* 70; *9* 50; *10* 50; *11* 51
Deuterium in Milky Way *10* 22
Diabetes, cure for *7* 13
Dial tester, electronic *6* 44
Diamond, impurities *5* 33
Diet, & aggression *8* 15; & cancer *7* 15; & pheromones *9* 19
Dinosaurs in Tibet *10* 7
Disease, how plants fight *9* 16-17
DNA, synthetic switch *7* 34
Down's syndrome in Kerala *2* 13
Drinking water & cancer *5* 13
Drought, as weapon *1* 22
Drugs, deviation from prescribed *5* 35
D'Souza, Victor S. *4* 25, 27

Earthquake prediction *2* 7; *6* 7; *10* 8; *11* 11
Eggs, re-laying of *4* 12; shells & altitude *12* 8
Electric fields, hazards of *1* 13
Electricity generator, wave-operated *7* 46
Elements 116 & 126 *2* 31
Ergonomic approach to comfortable living *3* 59
Evolution v/s creation *10* 7
Extra-terrestrial life *11* 11

Females, why some are males *10* 22; superfemales of athletics *10* 24
Fertiliser, liquid *10* 8
Fibres in food *8* 15
Fishermen, storm warning for *1* 45; *5* 9
Fire-proof doors *11* 8
Fire retardants & cancer *9* 7
Fish, poisonous *12* 36-42; technique of smooth sailing *7* 13; reducing energy loss *5* 13, 33; *7* 13; venomous *12* 26-35; water temperature *8* 15
Flushing cistern, leakproof *7* 47
Foam, why is it white? *10* 57
Friedman, Milton *6* 52; *11* 7
Fruit flies, learning *2* 30
Fuels, domestic *5* 60-63, *8* 7, *10* 6; solid *6* 62-65, *12* 6
Furniture, protection against termites *6* 11
Fusion power *6* 15-23; *7* 28-33
Futehally, Zafar *5* 36

Gajdusek, Carleton *6* 50
Gamma rays, protect furniture *6* 11; & neutron rays, Aryabhata study *8* 25
Gandhi, Mahatma & science *4* 47
Ganesan, S. *7* 46
Gardner, Martin *3* 30, 40
Garland canal scheme *2* 17-24; *5* 9; *6* 7
Geller, Uri *3* 30
Genetics, engineering techniques *9* 11; *11* 7; "Genes within genes" *11* 21; how tobacco virus

grows *10* 23; jumping genes *12* 20-21; Synthesis by Khorana *4* 32
Geosecs *10* 11-17
Glaciers, melting *3* 12
Gori, Geo B. *8* 29, 36
Green, J. *2* 32
Gun, only owner can fire *11* 10

Haemophilia *1* 7; *3* 8
Hang-glider, powered *11* 9
Hatching & auditory stimulus *8* 26
Hearing aids, improved *9* 18
Heart disease, & cigarettes *11* 8; & peanuts *7* 14; & polyunsaturated fats *7* 34
Heart, rubber for calf *1* 12
Heisenberg *2* 7
Hermaphrodites *6* 10
High altitudes, acclimatisation to *1* 13; and eggshells *12* 8
Histones, *5* 71-73
Holography, acoustic *11* 57-58
Homosexuality *8* 11
Horse, brain evolution *11* 8
Housing, underground *6* 13
Hybrids, animal-plant *2* 12; *3* 11
Hydrogen, generation from water *2* 45

Ice-sheets, advance and retreat of *1* 26
Immune system *1* 64; danger from body's *11* 9
In Lighter Moments:
Abernethy, John *4* 49; Babbage, Charles *6* 70; Bohr, Neils *5* 69; *10* 35; Cavendish *4* 49; Columbus, Christopher *11* 44; Dalton, John *1* 31; Darwin, Charles *3* 42; da Vinci, Leonardo *1* 31; Edison *1* 31; Einstein *7* 61; Faraday *4* 49; Flamsteed, John *11* 44; Fleming, Ambrose *5* 69; Franklin, Benjamin *2* 44; Haldane, J. B. S. *5* 69; *8* 22; Hegel *5* 42; Henslow *11* 44; Huxley, T. H. *6* 70; Jenner, Edward *6* 70; *9* 17; Marconi *4* 49; Marsh, James *3* 42; Maxwell, James Clark *1* 31; Millikan, Robert A. *10* 35; Needham, J. *7* 61; Newton *7* 61; *8* 22; *10* 35; Oxford University *3* 42; Sarton, G. *7* 61; Schonbein, C. F. *9* 17; Talbot *9* 17; Thales of Miletus *11* 44; Virchow, Rudolf *1* 31; Wilson, C. T. R. *5* 69; Young, Thomas *2* 44
Incomplete oesophagus, remedy for *1* 12
Indian Airlines & its pilots *9* 40
Influenza and swine flu *11* 9
Insecticide applicator *6* 44
Insulin as growth regulator *6* 30
Intelligence & family *4* 7
Intercom for mobike riders *2* 13
IQ, the Great Fraud *6* 33
IUD pill *4* 11
Iyer, R. H. *8* 38

Jacob, T. M. *4* 32, 33
Jadhav, S. S. *12* 52, 53
Jaluria, Y *10* 45, 46; *11* 39
Joglekar P. J. *1* 45; *7* 62, 67; *8* 60, 64
John, P. I. *6* 15, 23; *7* 28; *10* 5
Jokes & women *8* 12
Jupiter, life on *2* 11

Kamath, R. V. *10* 61
Kane, Dorothy Moyes *11* 32, 39
Kanhere, J. M. *3* 45
Kanungo, M. S. *4* 15, 24; *8* 8
Kapoor, R. C. *11* 13, 20
Karate, physics of *11* 8
Kelkar, B. D. *4* 67, 70; *5* 65; *6* 66; *7* 68; *8* 70; *9* 50; *10* 50; *11* 51
Khan, Badiuddin *1* 44; *2* 46; *3* 45; *4* 45; *5* 43; *6* 45; *7* 48; *8* 39; *9* 42; *10* 47; *11* 30; *12* 57
Khorana, a gene that works *4* 32
Kitchen design *4* 60-66
Knuckles, why do they rap? 9 41
Koshy, R. *1* 65
Krishnan, M. *5* 36
Kulkarni, M. M. *7* 75
Kumar, Jagdish *9* 16, 17
Kumaraswamy, P. *2* 22, 47; *5* 7

Lageos satellite *1* 9
Lakshminarayana, V. *2* 25
Lal, D. *10* 11, 17
Language & intelligence in ape & man *10* 36-44
Lasers, for acupuncture *6* 11; for entertainment *1* 12; free electron *12* 19
Lead poisoning *6* 10
Learn while you play: Conservation of momentum *6* 66-70; Fluids *9* 50-53; *10* 50-53; Gyroscopes *8* 70-75; Inertia *7* 68-72; Levers *5* 65-69; Motion *4* 67-70; Paper planes *11* 51-55
Learning *11* 9
Light emission, quantised *6* 29
Light, polarisation of *11* 22
Lion's hearts *4* 12
Lipscomb, William N. *6* 48
Liver, veno-occlusive disease *4* 30; transplantation *11* 23
Loads, psychology of carrying *5* 14
Lobster locomotion *5* 13
Loch Ness monsters *11* 11
Locusts *4* 13
Lop-winged plane *3* 12
Lovers, men & women unequal *9* 9
L-lysine, new chemical route to *3* 45

Madhusudana, N. V. *12* 11, 16
Magnetic stretching of gullet *1* 12
Magic & paraphysics *3* 30-42
Mahajan, Sulakshana *4* 60, 66
Mahatma Gandhi & the World of Science *4* 47-49; *7* 9
Maheshwari, S. C. *9* 11, 15
Maize dehusker *5* 43
Malaria, *5* 14; why the comeback? *11* 40-44
Malhotra, Kusum *9* 11, 15
Malshe, V. C. *7* 49
Mass, how astronomers measure *6* 71
Mars, polar caps, *5* 13; a close look at *7* 50-54; life on *9* 5; *12* 7; moon (Phobos) *12* 7
Mathematicians of Ancient India *1* 53; *2* 59; *3* 65
Meat from waste *4* 13
Membrane, super-permeable *4* 12
Memory, & dream *4* 13; pill *8* 12
Menstrual regulation *4* 53
Merchant, J. R. *9* 55
Merchant, S. M. *8* 52, 59
Mercury (planet) *5* 15
Metal joining by condensation *11* 31
Metallic glasses? what are *9* 57
Metallurgy, powder *8* 17-23
Meteor, following a *12 8*
Methane from biogas *6* 45
Mhatre, S. H. *11* 50
Microcephaly & warfarin *2* 12
Microscope, low-cost compound *9* 42; polarising *8* 9
Milk production in humans *8* 55
Milky Way, deuterium in *10* 22
Mitra, S. *11* 58
Mojave desert *3* 13
Monetarist revolution *6* 52
Monod, Jacques *1* 29
Monsoon experiment (MONEX) *5* 26-29
Moons, new types of *9* 8
Mosquitoes *5* 14; *11* 41
Mosquito traps from plants *7* 15
Mukherjee, A. K. *2* 63
Munshi, S. N. *2* 44; *3* 42; *5* 69; *6* 70; *7* 61; *8* 27; *9* 17; *10* 35; *11* 44; *12* 21
Myers, Norman *7* 41, 45

Names, effect of *6* 10
Nair, P. Madhavan *6* 50
Narasimha, R. *2* 32
Narlikar, J. V. *2* 62; *6* 72
Narayana Murthy, S. L. *8* 66
National Academy of Sciences *5* 11
Neptune, length of day *10* 9
Neurohormones & pest control *7* 36
Neutron & gamma rays, Aryabhata study *8* 25
News, social impact of *9* 7
Nickel cadmium battery *12* 57
Nitrogen fertilisation *2* 12
Nobel Prizes 1976 *6* 47-52, *11* 7
Noise stress near airport *2* 13
Notani, N. K. *1* 29, 69; *11* 22
Nuclear policy, India's *1* 7
Nuclear reactors, thorium-fuelled *4* 31
Nut, lockable *12* 7

Obesity, & brain *7* 15; & malnutrition *7* 37
Ocean, microcosm of particles in the *10* 11-17
Overnutrition *9* 7
Ozone, atmospheric *2* 11; SSTs & *5* 14

Paddy grain, mechanical drying *9* 42
Pain after amputation *4* 30
Pandit, L. K. *3* 15, 74
Panikar, J. T. *2* 15, 17
Paraphysics, magic & *3* 30-42
Pardivala, Jal D. *1* 47, 69; *2* 48; *5* 55; *7* 55; *8* 45; *9* 45; *11* 45; *12* 6
Particle physics, recent developments in *3* 15
Patel, Jashbhai C. *1* 53, 55, 69; *2* 59; *3* 57, 66, 74; *4* 47; *5* 70
Pathak, P. V. *1* 44; *6* 46; *7* 75
Pathak, V. P. *11* 40, 44
Patient's reward *10* 9
Pattanayak, S. *11* 40, 44
Patwardhan, S. R. *1* 44
Peanuts & heart *7* 14
Pearls, in fossils *4* 29
Penguin's vision *6* 13
Pennathur, Krish *3* 59, 74
Penicillin safety *3* 12
Pest control *4* 13, 29; by weeds *5* 15; & neurohormones *7* 36
Pesticides *6* 11
Petro-farms *5* 13
Petro-chemicals & olefin disproportionation *7* 48
Phèromone-diet, theory challenged *9* 19
Phosphenes *12* 63
Phul, P. S. *9* 16, 17
Pilot training *9* 33
Pipes, fixing on boggy grou *4* 12
Pisharoty, P. R. *5* 26, 29
Placebo effect *1* 11
Planetariums *8* 67
Plantimals *2* 12
Planning & the people *4* 9
Plants, how they control p *4* 29; & disease *9* 16; poi nous *12* 43-46
Plastic cords, coiling *10* 46
Play, in mammals *3* 13
Politicians' charisma *6* 11
Pluto *7* 35; temperature *1* 11
Plutonium theft *1* 41
Poisons, in fishes *12* 36-42; plants *12* 43-46
Polar ice caps, melting of *1* 19
Polio vaccines, Salk's & Sabi *12* 9
Powder metallurgy *8* 17-23
Pollution and children *11* 32-39
Polyunsaturated fats & the hea *7* 34
Prasad, Suresh *9* 43
Pregnancy and cats *4* 11; an vaccine *4* 11
Premack, David *10* 36, 44
Prenatal diagnosis *3* 12
Pressure indicator, remote ele tronic *10* 47
Progesterone & babies' IQ *6*
Protein-rich grains *9* 19
Prostaglandins, & abortion *4* 5 & asthma *9* 18
Psi particle *6* 47

Quantised light emission *6* 29

Radiator grille, anti-drag *4* 12
Raja, Jay *10* 18, 21
Rama *2* 24
Ramakrishnan, P. *8* 17, 23
Ranjitsinh, M. K. *6* 53
Rao, D. H. N. *10* 49
Rao, Krishnamurthy *1* 65; *5* 73
Rao, P. V. S. *2* 37, 68; *5* 9
Rao, S. Ranga Raja *6* 62, 65
Rao, Shanta S. *7* 73
Rat, reduction in India *3* 8 super killer *12* 55
Ray, P. K. *6* 61
Reactors, breeder *1* 33-41 thorium-fuelled *4* 31
Redkar, R. T. *5* 17, 25
Rege, D. V. *1* 55
Re-implantation of human eg *1* 27
Rele, J. R. *2* 26, 68
Remote sensing, by spectral signa ture *4* 71; & estimating cro yield *12* 19
Richter, Burton *6* 47
Right & left, handedness *6* 12 in the sexes *9* 7
Rindani, T. H. *8* 66
Robot postman *6* 12
Roy, Probir *6* 48
Roy, Bhaskar *9* 25, 32
Rubber heart *1* 12
Rubber, rival for *12* 9

Sadanandan, P. *8* 65
Saha, Meghnad *4* 35; *6* 24
Salt water, why it won't quenc thirst *11* 39
Sapre, A. V. *9* 18; *10* 23, 55; 23
Satellite, on leash *4* 13
Schaller, George B. *7* 38
Science, growth of, in India 35-43; *5* 47-54; *6* 24-28
Science Congress *7* 11
Science & International C operation *7* 17-27
Science or religion? *7* 7

ific revolution in search of
ueprint *9* 20-23; *11* 6
ists' psychology *3* 11
ions, venom *12* 52-53
rchins, commercial fishing
2 17
& water intake *8* 11
giri, N. *1* 15, 69
noosing kit, baby's *11* 9
, S. P. *1* 56, 69
i, V. A. *10* 25, 30; *12* 57
nna, K. R. *2* 67
ture verification system *1* 9
al, B. V. *9* 55
ng in the bathroom *9* 41;
6
phasing protector *7* 49;
6; *12* 6
heating mask *3* 11
amakrishnan, M. M. *3* 46,
hterhouse wastes, meat from
3
s', heart *9* 8; venom *12*
51; blood for antivenin *1* 25
melting by dust *7* 9
cell *10* 22; cooker *11* 30
suits *1* 13
, rescue in *1* 13
ral signature *4* 71
h; teaching the deaf *8* 13
ometer, cylindro *4* 45
Discus *11* 45, 49; Gym-
tics *5* 55-59; High jump *7*
61; Hurdling *1* 47-51; *5* 9;
8-51; Long jump *9* 45-49;
t putt *8* 45-51; *12* 6
injuries *3* 13
ran, V. *12* 21
& ozone layer *5* 14
um, movable *9* 43
measuring the masses of
l

Sterilisation, compulsory *2* 26
Stoves, safer wick *11* 30
Sugar complex, case for *1* 43; *4* 7
Sugavanam, G. *10* 49
Sunglasses and eyesight *12* 7
Supercentenarians *4* 20
Superheavy elements *2* 31
Sweeteners, new *10* 7
Swine flu, deaths *6* 13; & human flu *11* 9
Swings, physics of *6* 12
Syphilis vaccine *1* 11
Syringe, self-injecting *1* 12

Tartrazine *6* 13
Test-tube baby *1* 27
Textiles, finishing gimmicks in *10* 25-30
Thermoelectricity ? what is *10* 55
Thrombosis *6* 29
Ting, Samuel *6* 47
Trains, faster *1* 7
Transmitters, for warning fishermen *1* 45; *5* 9
Transplants, and dogs to sniff compatibility *7* 12; of liver *11* 23
Trees, let's get to know:
Rain tree *10* 31; Gul mohr (Flame of the forest) *10* 33; Peacock flower *10* 33; Coral tree *10* 33; Cassia (Indian laburnum) *10* 34; Copper pod *10* 35; Asupala *11* 29; Wild almond *11* 27; Fountain tree *11* 26; Silk cotton *11* 25; Baobab *11* 26; Tulip tree *11* 26; Sausage tree *11* 27; Sterculia *11* 28; Banyan *12* 23; Pipal *12* 24; Figs *12* 23-25
Tree bark blotters *7* 13
Trichomes as pest protection *4* 29
Tsunamis, predicting *8* 13
Tryptophan & aggression *8* 15
TV, trouble shooting in *8* 60; antenna *7* 62-67; *11* 6; flicker in images *3* 27
Twins, a season for? *10* 7

Uberoi, C. *8* 41, 44
Udgaonkar, B. M. *7* 17, 27; *10* 5; *11* 7
Underground storage tank *1* 9; housing *6* 13
Unique numbers for human beings *2* 47; *5* 7; *7* 9
Uranium, simpler exploration & recovery process *8* 37
Uranus, how long is the day? *10* 9; ring around *11* 21

Vad, N. E. *12* 51
Venkatavaradan, V. S. *3* 66; *7* 50, 54; *9* 5, 41; *10* 11, 17, 57; *11* 39
Venom, in sea animals *12* 26-35; in snakes *12* 46-51; in scorpions *12* 52-53
Venus *7* 14; *10* 9
Verghese, Joseph *10* 55
Viking mission, results *3* 66; *12* 7
Viricides from sea weeds *2* 12
Virus, bank *1* 9; slow *6* 50; sun fat for *10* 8; and wine *11* 8
Vision & alcohol *9* 9
Viswanathan, N. *12* 43, 46
Vitamin C for cancer *7* 12

Warfarin, teratogenic effects *2* 12
Water infiltration for soil, automatic *8* 39; storage in old aquifers *1* 9
Water jets, cutting with high speed *10* 45
Water lens *1* 44
Water needs, India's *2* 15
Water, preserve with *10* 7
Weather, as weapon *1* 15-24; krypton & *3* 28; Sun's influence on *1* 26
Weeds & pest control *5* 15; on roads *6* 10
Wheat, high-protein *2* 11
Whitaker, R. *12* 47, 51, 52
Whistlers *8* 41-44
Wine against viruses *11* 10
Wild dog *1* 59; *4* 7
Wind instruments, acoustics *5* 31
Wolf *1* 56-60; *4* 7
Women & talkativeness *1* 25

Xerography? what is *10* 54
X-rays & children *3* 8
X-rays peer through crystals *9* 8
X-ray sources, mapping new *12* 7

You Too Can Do It: Adjustable voltage Zener diode *5* 75; Electronic voltmeter adaptor for multimeter *2* 65; IC Baby alarm *12* 62; IC code practice oscillator *11* 59; Integrated circuit amplifier *8* 26; Photo flash slave for electronic flash *10* 57; Short-proof power supply *1* 67; Solidstate defroster timer *3* 71; Solidstate millivoltmeter *7* 76; Solidstate sequential turn signal *6* 73; Telephone amplifier *9* 58

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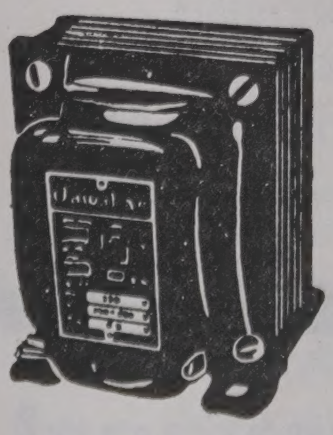

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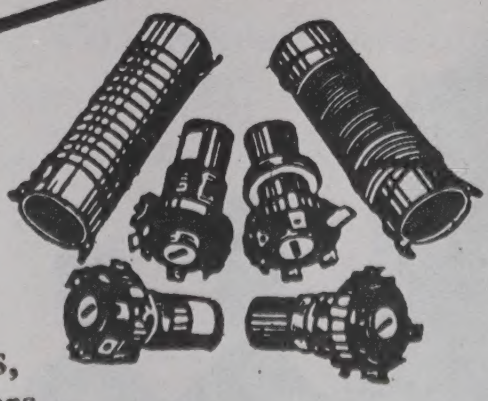

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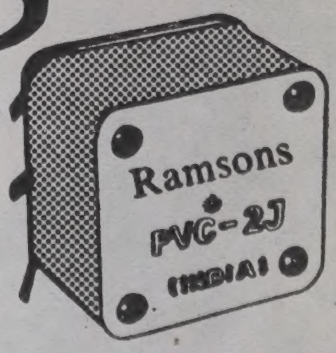

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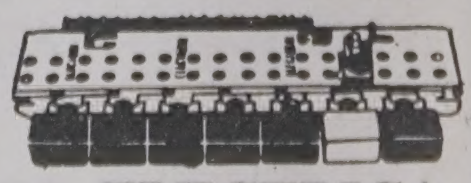

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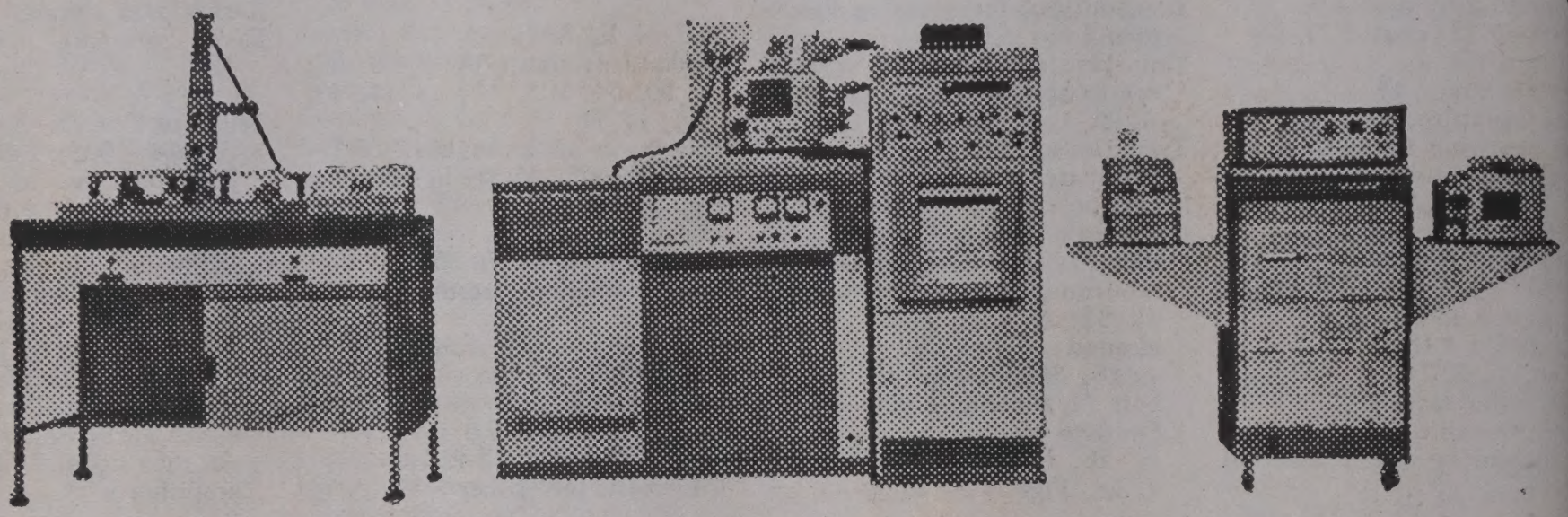

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